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Experimental Study of a New Cooling Technique for Photovoltaic Systems

Présenté par

- **MEDJOUDJ Tesnim**
- **SOUFI Lina**

Soumis au jury compose de

NECIB Hichem	M.C. A	U.K.M Ouargla	Président
MAAMMEUR Hocine	M.C. B	U.K.M Ouargla	Examinateur
HADJADJ Abdessamia	M.C. B	U.K.M Ouargla	Co-Encadreur
BENMENINE Djamal	M.C. B	U.K.M Ouargla	Encadreur

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شكر وتقدير

أرى إلزاما عليا تسجيل الشكر وإعلامه ونسبة الفضل الى أصحابه استجابة لقول النبي صلى الله عليه وسلم " من لم يشكر الناس لن يشكر "

علامة شكر المرء إعلان حمـــده فمن كتم المعروف منهم فما شكر فالشكر أولا لله عز وجل على أن هداني لسلوك طريق البحث والتشبه بأهل العلم و إن كان بيني و بينهم مفاوزكما أخص بالشكر أستاذتي الكرماء و معلمي الفاضل المشرف على هذا البحث الدكتور بن منين جمال كما اشكر و رئيس اللجنة الدكتور نصيب هشام والأستاذ المناقش الدكتور معمور حسين كما لا ننسى الدكتور حجاج عبد السميع فقد كانوا حريصين على توجهي إلى ما يرى بأرق عبارة و ألطف إشارة، فلهم مني وافر الثناء و خالص الدعاء. كما أشكر السادة الأساتذة وكل الزملاء وكل من قد لي فائدة أو أعانني بمرجع أسأل الله أن يجزيهم خيرا وأن يجعل عملهم في ميزان حسناتهم

رحمة الله على الدكتور الفقيد الأستاذ قراح سليم الذي كان مشرفا لنا ادعو الله ان يتغمد فقيدنا الرحمة والمغفرة وان يرزق اهله الصبر والسلوان

SUMMARY

Photovoltaic solar panels directly convert solar energy into electrical energy but their efficiency is low. The rest of the energy is mostly converted into heat. Although the conversion efficiency of photovoltaic panels is low, heating them increases the temperature of the photovoltaic cells, which leads to a significant decrease in their efficiency and technical life. In This study, it was done Cooling the photovoltaic panels using wet burlap, manufactured with geothermal heat, where they were combined by placing the panels in an aluminum casing to receive the cold air from underground.

The cover is on a tube connected to small channels and small underground channels. These channels in the ground, connected to a fan, allow air to be transferred to the burlap to cool it. Moreover, since the burlap is attached behind the solar cell the thermal load is reduced to a minimum. This system works to absorb the heat extracted from the panel into the burlap. Experimental results showed that the cooling system is able to remove about 5 degrees of heat compared to the other panel

الملخص

تقوم الألواح الشمسية الكهروضوئية بتحويل الطاقة الشمسية مباشرة إلى طاقة كهربائية ولكن كفاءتها منخفضة. يتم تحويل بقية الطاقة في الغالب إلى حرارة. على الرغم من أن كفاءة التحويل الألواح الكهروضوئية منخفضة، إلى أن تسخينها يزيد من درجة حرارة الخلايا الكهروضوئية، مما يؤدي إلى انخفاض كبير في كفاءتها وعمرها الفني. وفي هذه الدراسة تم ذلك تبريد الألواح الكهروضوئية باستخدام الخيش المبلل، المصنع بالحرارة الأرضية، حيث تم دمجها عن طريق وضع الألواح في غلاف من الالمونيوم لاستقبال الهواء البارد القادم من تحت الأرض والغطاء يكون على أنبوب متصل بقنوات صغيرة وقنوات صغيرة تحت الارض. تسمح هذه القنوات الموجودة في الأرض والمتصلة بمروحة الى الخيش لتبريده علاوة على ذلك نربط الخيش خلف الخلية الشمسية لتقليل الحمل الحراري الى أدنى مستوى، يعمل هذا النظام على امتصاص الحرارة المستخرجة من اللوحة إلى داخل الخيش. وأظهرت النتائج التجريبية أن نظام التبريد قادر على إزالة حوالي 5 درجات من الحرارة مقارنة باللوحة الأخرى .

إهداء

(وَآخِرُ دَعْوَاهُمْ أَنِ الْحَمْدُ لِلَّهِ رَبِّ الْعَالَمِين)

الحمد لله حبا وشكرا وامتنانا على البدء والختام بعد تعب ومشقة دامت الخمسة سنوات في سبيل العلم حملت في طياتها امنيات الليالي وأصبح عناني اليوم للعين قرة ها انا اليوم أقف على عتبة تخرجي اقطف ثمار تعبي وارفع قبعتي بكل فخر فاللهم لك الحمد قبل ان ترضى ولك الحمد اذا رضيت بعد الرضا الذي وفقني على إتمام هذا النجاح وتحقيق حلمي وبكل حب اهدي ثمرة نجاحي وتخرجي الي نفسي الطموحة وانتهت بنجاح ثم الى كل من سعى لإتمام مسيرتي الجامعية.

اود ان أخص بكلمة شكر خاصة فلك الفضل الأول في كل ما حققته لقد كنتي هديتي من الله والحنان وملاذ روحي السند والعون في كل خطوة رحلتي ودعمك كان دافعا الاستمرار وعدم الاستسلام فكلماتي هذه تعبر عن قطرة مما في قلبي

امي

الى من زين اسمي بأجمل الألقاب الى داعمي الأول وسندي وقوتي بعد الله

ابي

الى من شد عضدي بهم فكانوا خير المعين الى كتفي وحمايتي وسياج ظهري لكم مني خالص الشكر

اخوالي وخلاتي

الى من كانت دعواتهم حاضرة مسيرة لي الطرق كله من الصعاب والأزمات

جدتي وجدي

الى الداعمين لي ومصدر الهامي من واصلو تشجيعي دون كلل او ملل الذين جمعتني بهم الدراسة والجامعة لكم مني خالص الشكر

صديقاتي وفقكن الله

الى من امدوني بالقوة والتوجيه وامنو بي ودعموني في الأوقات الصعبة واوصلوني الى هنا

عائلتي الكريمة

تسنيم مجوج

من قال ان لها نالها لم تكن قصيرة ولم ينبغي لها ان تكون لم يكن الحلم سهلا والطريق كان محفوفا بالتسهيلات ولكن فعلتها ونلتها حمدا لله شكرا وحبا وامتنانا بفضله ها انا اليوم انظر الى حلم طال انتظاره وقد أصبح واقعا افتخر به.

الى ملاكي الطاهر وقوتي بعد الله وداعمتي الأولى والابدية حياتي ما كان لها وجود كنتي خير السند وحير العوض

امي

الى من دعمني بلا حدود واعطاني بلا مقابل

ابي

الى من قيل فيهم: "سنشد عضدك بأخيك" الى من مد يده دون او ملل وقت ضعفي ادامكم هلال وضلعا ثابت

اخواتي ايمن وادم واياد

الى من امن بقدراتي وامضيت معهم أحلى أيام وأجمل ذكريات

عائلتي

الى من كان تذكرني بقوتي وتقف خلفي كظلي

صديقتي وداد

وأخيرا وليس أخيرا اشكر استاذي ومؤطري أستاذ جمال بن منين على كل الدعم الذي قدمه لي ولصديقتي واشكر كل من ساهم في تعليمي منذ الصغر وفي الأخير نتمنى الترحم على روح فقيدنا الأستاذ قراح سليم رحمه الله وجعل مثواه الجنة.

السوفي لينة

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Worldwide electricity consumption is growing at a continuous rate of 3% annually, and this growth is mainly due to the growing population, economic and technical development, as well as people's aspiration to create a more comfortable living environment. However, over-reliance on traditional fossil fuels to meet this demand leads to negative impacts on the environment, such as increased global warming, air pollution, climate change, and the occurrence of acid rain. In addition, these traditional resources are expected to run out within the next few centuries [1]

To address these problems and the associated environmental and economic challenges, renewable and sustainable energy sources, such as solar energy, are promising for power generation as they are safe, clean and environmentally friendly. The various technologies used to convert solar radiation into electricity include photovoltaic, thermal, and chemical cells. Among these technologies, the most widely used are photovoltaic cells, where electricity is generated directly through the use of semiconducting materials, such as silicon.

Photovoltaics are mainly used in photovoltaic systems and concentrated solar power systems, but PV technology is the most widely used, especially in grid-connected or stand-alone systems in homes. Solar energy technology has witnessed significant development in the last two decades to become one of the most important sources of renewable energy after hydroelectric energy and wind energy.

Solar electricity generation technology has a small environmental footprint, low maintenance cost, and other advantages such as operational simplicity, absence of moving parts, and silent operation. Thanks to the low cost of PV modules, their use has been greatly expanded around the world. It is important to note that the conversion efficiency of photovoltaic solar cells ranges between 14-25%, and this efficiency varies depending on the external operating conditions, which requires continuous studies and development to maintain their optimal performance.

Although Algeria is considered one of the regions with the highest average annual solar energy in the world, it faces great challenges as a result of its difficult environmental conditions, as most of its lands include arid and semi-arid areas.

Given these challenges, the current research seeks to study and analyze how to mitigate the impact of environmental factors on the efficiency of PV systems installed in these arid and semi-arid regions. Contribution was made in this field by conducting real outdoor experiments to study the conditions of the desert area in the city of Ouargla, southern Algeria, and evaluating the effect of climatic factors such as high temperature on the performance of photovoltaic modules.

The first chapter presents an introduction to global energy and electricity statistics in Algeria, with the potential for exploiting renewable energy and photovoltaic energy in particular. The second chapter presents the various experiments used in refrigeration, through which we were able to obtain the basic idea about the work. The third chapter was specifically devoted to the experimental performance that we conducted**.** -

CHAPETER 01

World Energy consomption

1. INTRODUCTION

Solar photovoltaic energy is considered one of the most promising and widely used renewable energies, because of its many advantages, such as cleanliness and lack of pollution. It also reduces CO2 emissions and protects the environment, making it a more sustainable option to meet the needs of the global electricity market. This chapter deals with energy consumption in the world and in Algeria in particular and its promising potential in the country.

2. GLOBAL ELECTRICITY CONSUMPTION

In 2023, a significant increase in renewable energy capacity was recorded, with renewable electricity additions reaching approximately 507 GW, representing an increase of approximately 50% compared to the previous year, thanks to continued policy support in more than 130 countries. This global acceleration in growth has been mainly driven by year- on-year expansion in the PRC market, where solar PV saw a 116% increase and wind a 66% increase. These increases are expected to continue in the next five years, with solar and wind accounting for a record 96% of expected additions, given their strong cost competition compared to fossil and non-fossil alternatives in most countries, as well as continued political support for them.[2]

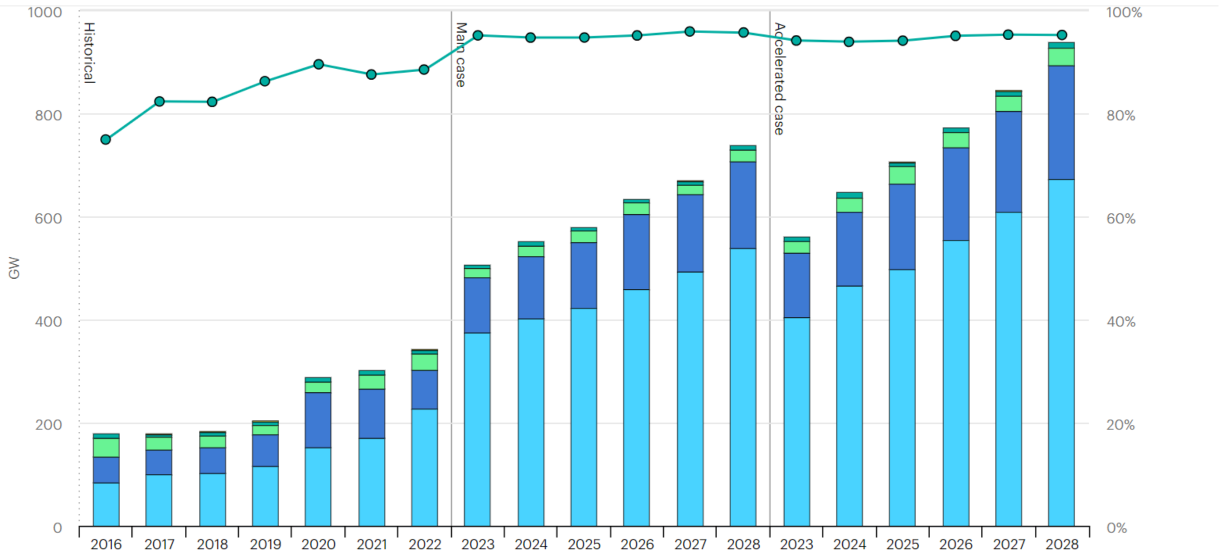


Figure 1-1 Total gross electricity production 2016-2028

3. RENEWABLE ELECTRICITY

A significant increase in renewable energy capacity was recorded in 2023, with renewable electricity additions reaching approximately 507 GW, representing an estimated increase of approximately 50% compared to the previous year, thanks to continued policy support in more.

Then 130 countries, resulting in a significant change in trend. Global growth. This global acceleration has been mainly the result of year-on-year expansion in China's booming market for solar PV (+116%) and wind energy (+66%). Additions to renewable energy capacity are expected to continue to increase in the next five years, with solar PV and wind energy additions expected to double by 2028 compared to 2022, continually breaking records over the forecast period to reach approximately 710 gig watts. At the same time, additions to hydropower and bioenergy capacity are expected to be lower than over the past five years, as a result of slower development in emerging economies, especially in China.[3]

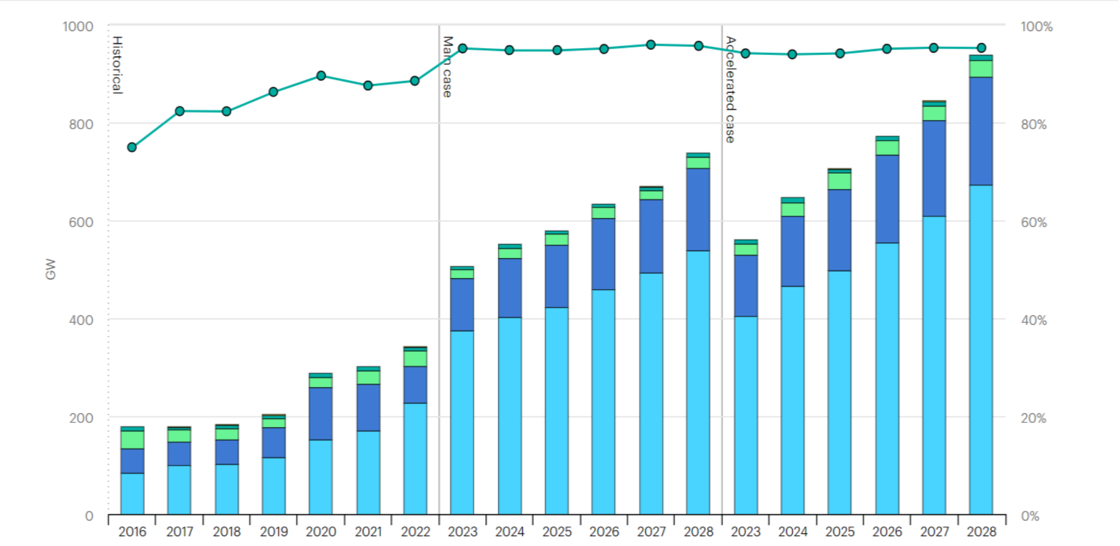


Figure 1-2 Renewable electricity capacity additions by technology and segment, 2016-2028

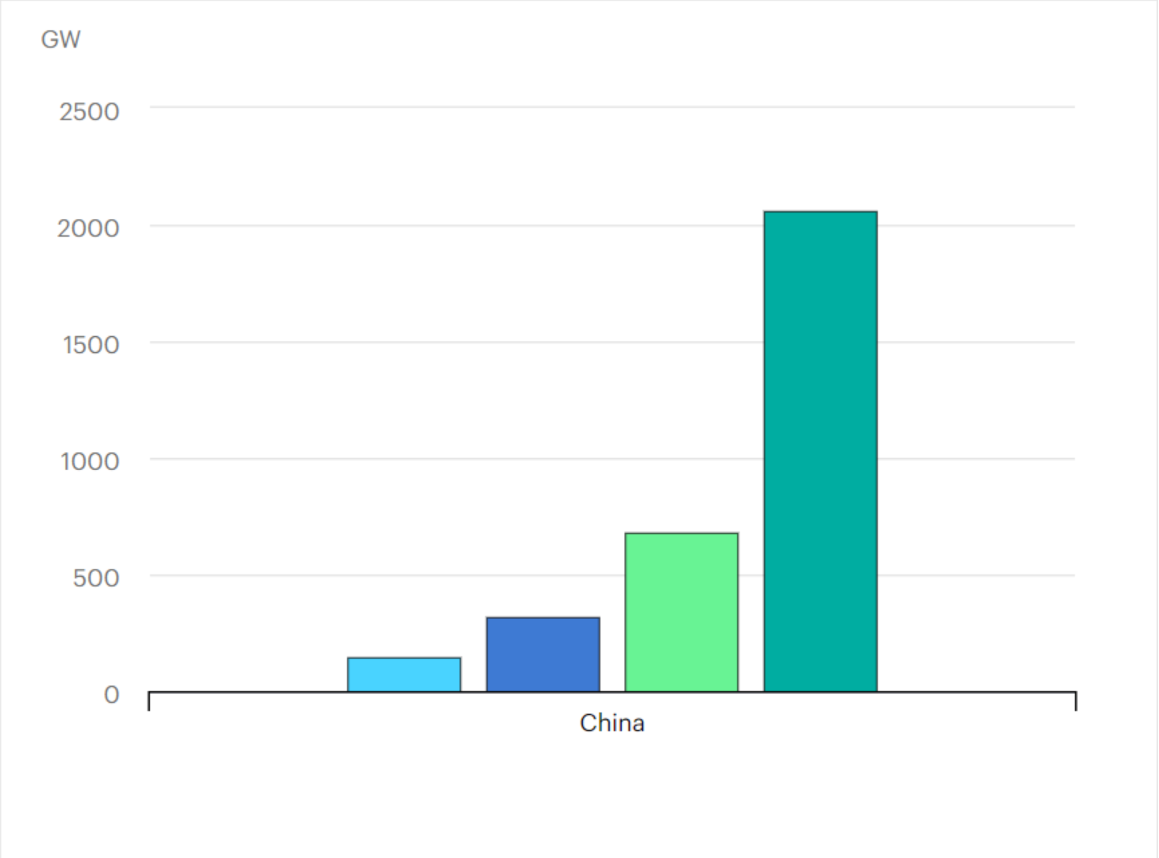


Figure 1-3 Renewable electricity capacity growth in China 2005-2028

According to the report, solar and wind power now generate about 13.4% of the world's total electricity generation, a rise of nearly nine percentage points since 2015. In addition, the report notes that clean sources — including solar, wind, and others — it now generates nearly 40% of the world's total electricity. The level of carbon dioxide emissions from power generation will reach a new record low in 2023, falling 12% from its peak in 2007.

The world is at a turning point, with fossil fuel production expected to decline by 2% worldwide this year, as a result of the increased volume of renewable energy generation expected compared to fossil fuels. Renewable energy has already held back fossil fuel growth by two-thirds over the past decade, and half of the world's economies have passed peak fossil fuel electricity generation. OECD countries are at the forefront of this transition, with energy sector emissions falling to 28% lower levels since their peak in 2007.

Solar has overtaken wind as the largest contributor to clean energy for the second year in a row, and has been the fastest-growing source of electricity generation for 19 consecutive years. Between 2022 and 2023, solar additions rose by 76%.[4]

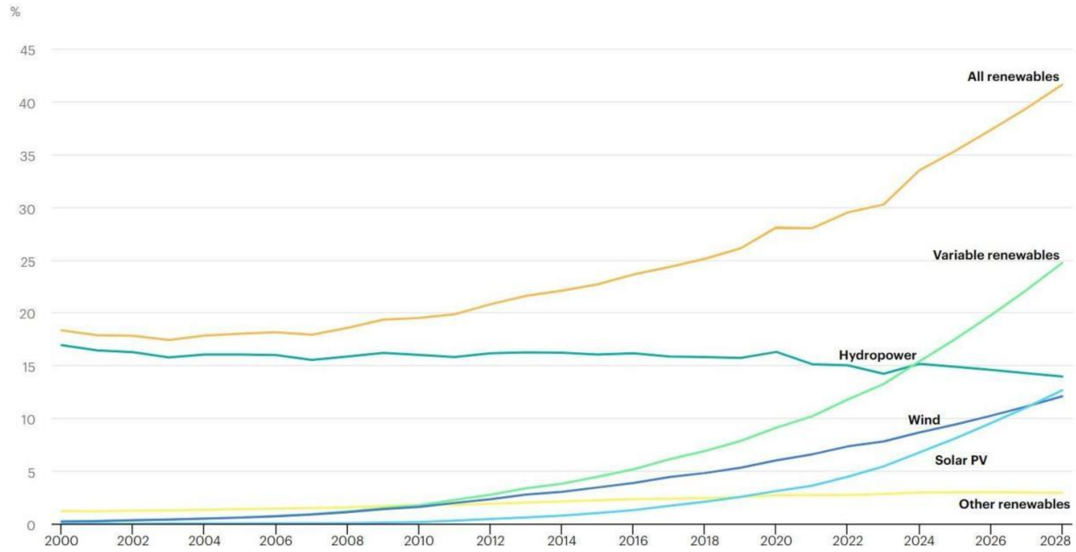


Figure 1-4 Share of renewable electricity generation by technology, 2000-2028

The US, EU, India and Brazil are expected to see solar PV and onshore wind additions double through 2028 compared to the previous five years. This significant increase is due to supportive policy environments and improving economic attractiveness of solar and onshore wind. In the European Union and Brazil, growth in rooftop solar PV is expected to outpace large-scale plants, as residential and commercial consumers seek to reduce their electricity bills amid rising prices.

In the US, inflation control was a catalyst for accelerated additions despite supply chain issues and near-term trade concerns. In India, an expedited auction schedule for onshore wind and utility-scale solar PV is expected to drive accelerated growth.

The expansion of renewable energy has also begun to accelerate in other regions of the world, especially in the Middle East and North Africa, mainly due to political incentives that take advantage of the competitive costs of solar and onshore wind. Despite the recovery in renewable capacity growth in sub-Saharan Africa, the region remains underperforming relative to its resource potential and electricity needs.[5]

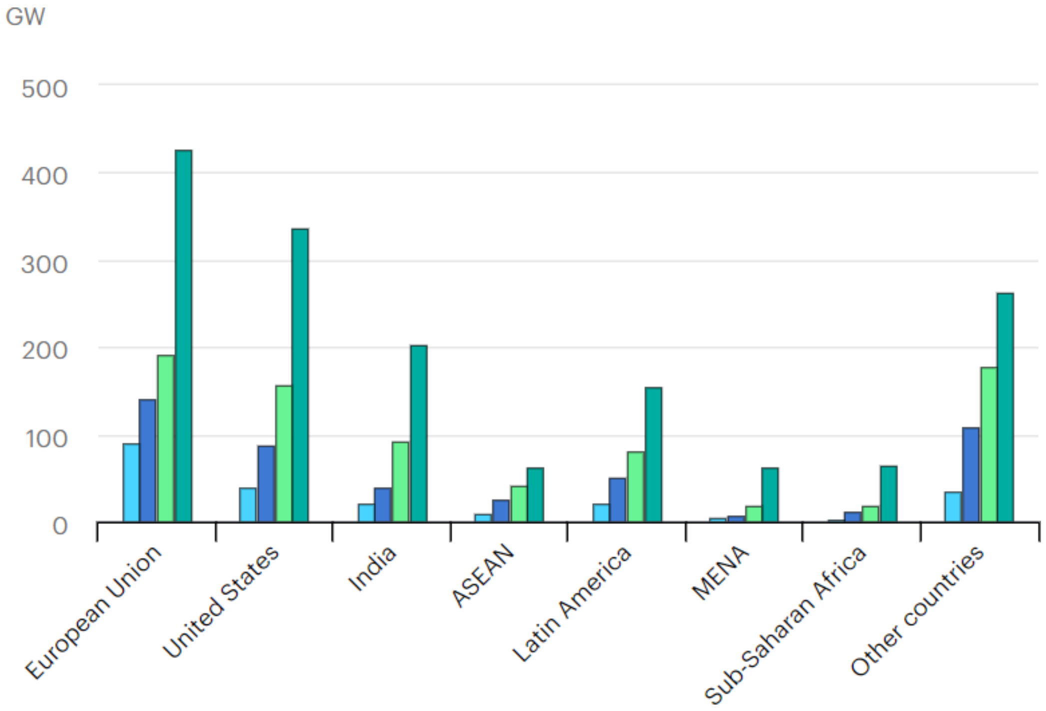


Figure 1-5 Renewable electricity capacity growth by country or region 2005-2028

4. ENERGY PROFILE IN ALGERIA

Algeria stands out for its abundant and diverse natural resources, as it possesses huge reserves of natural gas, making it one of the highest countries in the world in terms of reserves. In addition, the country has large oil fields and a variety of other resources such as gold, iron, zinc, phosphate, uranium, and others. Algeria's role is not limited to that, but it also plays a vital role in global energy markets as a major producer and exporter of hydrocarbons, in addition to its promising participation in the renewable energy market due to its distinguished geographical location and the diversity of its natural resources. Etude et amélioration des systèmes de conversion photovoltaïque dans les zones arides et semi-arides.[6]

4.1. SOLAR

Algeria receives direct solar radiation estimated at 169,440 kWh/m2/year, indicating the potential for generating solar energy of up to 3,000 kWh/year. The country's desert is among the regions with the highest average solar radiation and temperatures in the world, with insolation duration ranging from 2,000 to 3,900 hours per year, with horizontal surface radiation ranging from 3 to 5 kWh/m2.

The country has a network of 78 meteorological measuring stations, operated by the National Meteorological Service (ONM) and distributed throughout the country. Considering the distribution of radiation and temperature in the country, the potential for solar energy generation in the desert region with an area of 2,048,297 square kilometres has been demonstrated. It is estimated that about 168 x 1012 kWh/year can be generated by exploiting 50% of the available space with an efficiency of 10%.[7]

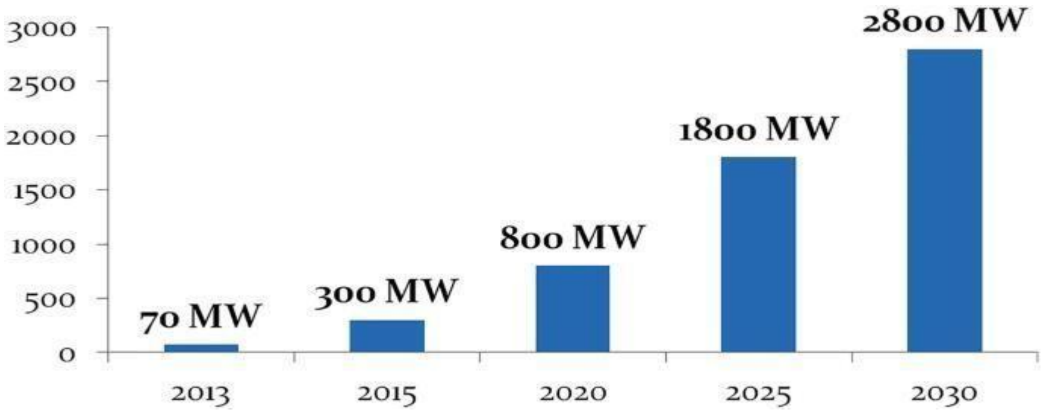


Figure 1-6 The possibility of solar energy in Algeria

4.2. GEOTHERMAL ENERGY

In Algeria, the country has significant geothermal potential, estimated at approximately 460 GWh annually. Temperatures in some areas of Algeria exceed 45 degrees Celsius, with the highest temperatures reaching 98 degrees Celsius and 118 degrees Celsius recorded in Hammam Meskhoutine and Biskra, respectively. These areas are located in the western part of the country. These sources have been documented by CDER, with temperatures in a third of the sources exceeding 45°C.[8]

To date, applications of geothermal energy in Algeria are limited to agriculture, such as heating greenhouses and aquaculture, in addition to use in space heating, sanitation and balneotherapy. However, more economic and environmental applications of these rich natural resources could be explored in the future, representing important opportunities to enhance sustainability and diversify the country's energy sources

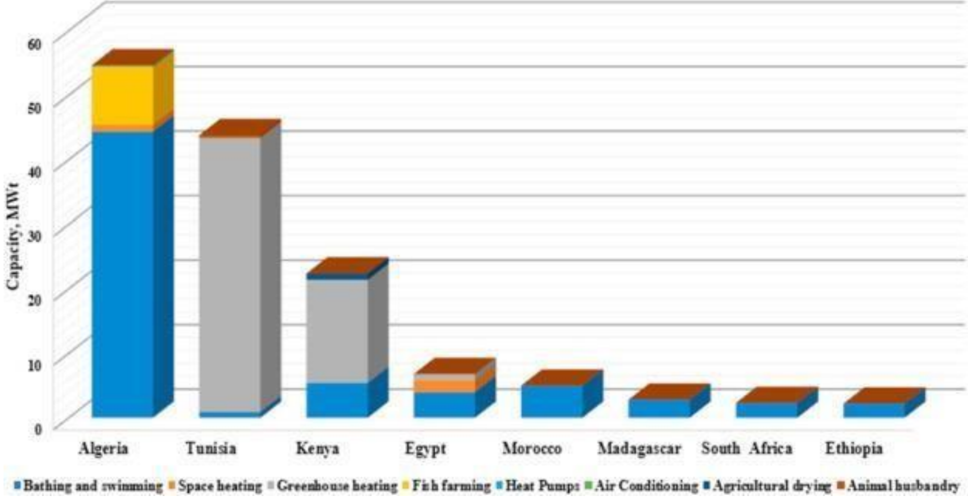


Figure 1-7 Geothermal energy use in Algeria

5. WHAT IS A SOULAR CELL?

The photoelectric effect is the phenomenon that occurs when a photovoltaic cell is exposed to sunlight, generating a voltage or electric current. This effect is fundamental to the operation of solar panels, as solar panel cells convert sunlight into electrical energy. The photoelectric effect was first discovered in 1839 by scientist Edmund Becquerel, who observed an increase in voltage when his silver plates were exposed to sunlight during his experiments with wet cells.

The photovoltaic effect occurs in solar cells, which consist of a p-n junction between two different types of semiconductors: p-type and n-type. When this junction is formed, an electric field is created in the junction area, with electrons moving to the positive p-side, while holes move to the negative n-side. This field causes negatively charged molecules to move in a certain direction, while positively charged molecules move in the opposite direction, generating an electric current.[9]

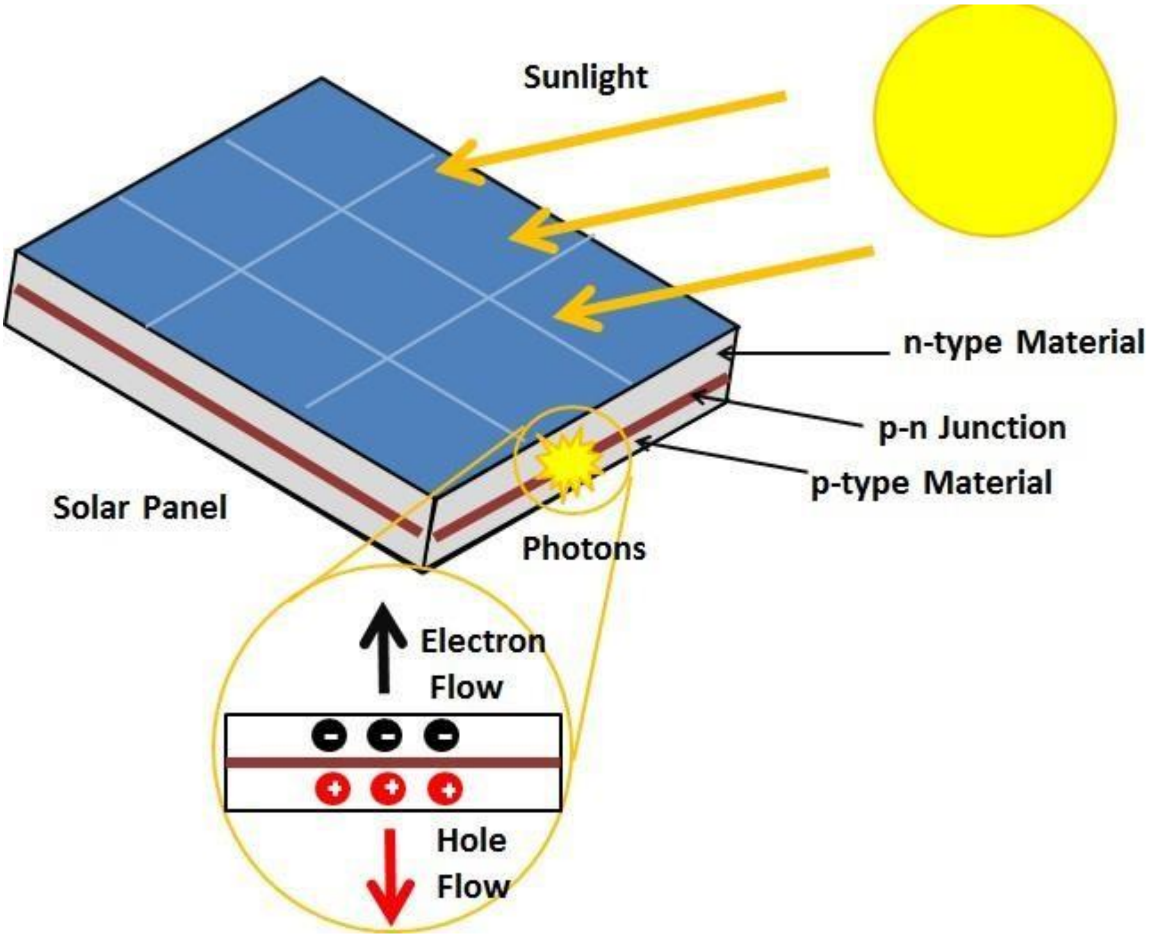


Figure 1-8 A diagram showing the photoelectric effect.

6. SOULAR CELLSOLLR CELL GENERATIONS

There are several photovoltaic materials that are commonly used in solar cell production of energy. This section provides a brief review of the basic absorption layer materials currently in use.[10]

6.1. FIRST GENERATION SOULAR CELL

The first generation of solar cells is produced using silicon wafers, the oldest and most popular technology due to its high energy efficiency. Silicon chip technology is divided into two subgroups:

- Monocrystalline silicon solar cell.

- Polycrystalline silicon solar cell.[11]

A) MONOCRYSTALLINE SILLICON SOLLR CELL

A monocrystalline solar cell is made from single crystals of silicon using a process called the Czochralski process. During this process, silicon crystals are cut from large ingots. These single crystals require careful processing, including a “recrystallization” process, which makes these cells more expensive and complex to manufacture. The efficiency of monocrystalline silicon solar cells ranges between 17% and 18%.[12]

B) POLYCYSTALLIN SILLICON SOLLR CELL(Poly-Si or Mc-Si)

Polycrystalline solar cells typically consist of several different crystals connected together to form a single cell. Polycrystalline solar cells are more economical to process, as they are produced by cooling a graphite mold filled with molten silicon. These cells are currently the most common, thought to have accounted for about 48% of global solar cell production in 2008. As molten silicon solidifies, various crystal structures form. Although they are cheaper to manufacture compared to monocrystalline silicon solar cells, their efficiency is lower, ranging from 12% to 14% [13]

6.2. SACANDS FIRST GENERATION SOULAR CELL

A) THIN FILM SOLLR CELL

Most thin-film and a-Si solar cells are second generation solar cells, and are more economical compared to first generation solar cells made of silicon wafers. Crystalline silicon cells have light-absorbing layers up to 350 micrometers thick, while thin-film solar cells have very thin light-absorbing layers, typically about 1 micrometer thick. Thin film solar cells are classified into the following types:

- a-Si (amorphous silicon).

- Cadmium telluride.

- CIGS (copper indium gallium selenide).[14]

B) FOR FILM CADMIUM TELLURIDE (CdTe) SOLLR CELL

Among thin-film solar cells, cadmium telluride (CdTe) is one of the prime candidates for developing low-cost and economically efficient solar cells. CdTe has a bandgap of about 1.5eV, a high optical absorption coefficient, and chemical stability, making it an attractive material for the design of thin-film Soller sells.

6.3. THIRD GENERATION SOULAR CELL

Soller technology is considered one of the most promising innovations, as it has not been commercially researched in detail yet. The types of most of these advanced cells include:

1) Third generation cells based on nanocrystals.

2) Third generation cells based on polymers.

3) Third generation dye-enhanced sells.

4) Third generation concentrated cells.[15]

CHAPETER 02

Different cooling exeperiment

1. INTRODUCTION

Solar photovoltaic systems are one of the most important renewable energy sources used around the world. However, one of the main factors that leads to low efficiency of these systems is the high temperature in the solar panels, which negatively affects their overall performance. In addition, high temperature can accelerate the deterioration of the materials used in manufacturing the panels, which increases maintenance costs and reduces the lifespan of the photovoltaic system. Therefore, it is important to include a cooling system as a function of reducing solar panel heating. This chapter explains the various factors that affect on the board and some previously used cooling systems

2. INFLUENCE OF ENVIRONMENTAL FACTORS ON PV SYSTEMS

2.1 Effects Of Temperature

The efficiency of electricity production from photovoltaic modules depends greatly on the temperature of the module. As the temperature increases, the efficiency of electrical conversion decreases. PV modules convert only a small percentage of the received solar energy into electricity, and the rest into heat. There is a strong relationship between the module temperature and the band gap of the photovoltaic cell material, as the band gap generally decreases under conditions of high operating temperatures, which affects the cell's ability to absorb longer wavelength photons and increases the temperature.

Without cooling, electrical efficiency decreases by 0.03% to 0.05% for every 1°C increase in solar cell temperature. Thermal dissipation and absorption properties of the encapsulated or covered materials affect the PV performance as well. Research is currently being conducted to enhance energy recovery from PV modules by developing cooling technologies.[16]

2.2 Effects Of Dust Accumulaiion

The efficiency of PV modules is negatively affected when there is the presence of dust, water vapor, air particles and other pollutants in the atmosphere, which prevents sufficient solar light from falling on the PV panel. Dust particles in the air can scatter and reduce the amount of solar radiation reaching the PV module, thus reducing its performance. The dust can also form a thick layer on the surface of the photovoltaic module, which changes its optical properties and reduces its efficiency in absorbing light and converting it into electrical energy, thus reducing energy production.

Dust accumulation rates are affected by environmental factors such as wind speed, humidity and rainfall, as well as by dust sources, particle type, PV module technology and roof covering. The effect of excessive dust accumulation is more severe in desert areas, where dust density is high and there is little rainfall.

Studies indicate that the rate of efficiency degradation in photovoltaic modules can reach 6-7% per month in some areas, and may increase to 13% during long periods without cleaning the modules. In addition, energy production may be reduced by half or less without cleaning the units, a reduction of approximately 17.4% per month in some cases. The impact of these harmful factors increases with a decrease in the efficiency of photovoltaic energy in cases of the presence of air pollutants, toxic gases, and suspended particles, as energy production can decline by more than 60%.[17]

Figure 2-1 Effect of dust deposition on photovoltaic panels:

2.3 EFFECTS OF SOILING

Dust buildup can also contaminate PV modules. In humid environments, dust particles settle on the surface of PV modules and absorb moisture from the air to form a clay layer. High atmospheric humidity greatly affects the adhesion strength between dust particles and the surfaces of PV modules. Therefore, dust accumulation increases with increasing absolute humidity. In addition, the condensation of steam on the PV module leads to the formation of capillary bridges in the gaps between particles and the surface, which enhances the adhesion of particles to the surface and facilitates dust accumulation. The end result of contamination is light and severe shading on the PV module, which significantly reduces its performance. Atmospheric fog and smoke cause light shading, while soil or clay buildup causes heavy shading. Although heavy shading results in lower module voltage, unshaded modules still receive solar radiation, maintaining PV power generation. The effectiveness of pollution in reducing PV power varies by geographic location, due to different effects of dust on light transmission. Studies have shown that there is a good relationship between the mass of pollution and the loss of photovoltaic energy. In some cases, the loss of PV energy is proportional to the soil mass. Studies show that natural cleaning by rain, combined with mechanical cleaning with liquids or water, can solve this problem.[18]

2.4 EFFECTS OF WIND VELOCITY

Studies show that rising temperatures greatly affect solar cells, as they show a sensitive effect on wind speed regardless of its direction. The shape and surface structure of PV modules have a noticeable impact on the cooling process. For example, grooved glass cover surfaces may work well at low temperatures and high wind speeds to cool the unit. However, the cooling effect is much greater on a flat surface in low wind conditions.

Studies have shown that we can reduce the operating temperature by 3.5°C at a wind speed of 10 meters per second using a grooved glass cover. The temperature can also be reduced by up to 10°C at wind speeds between 2.8 and 5.3 meters per second. In addition, the wind tends to reduce dust deposition on the surface of the PV module by transporting dust particles. For example, a study in Egypt showed a reduction in dust deposition on the unit due to wind. However, this can have a negative impact in desert areas.[19]

3. EXPERIMENTAL STUDIE TO IMPROVE THE EFFICIENCY OF PHOTOVOLTAIC PANELSE

3.1. Passive Cooling Methods That Use PCM

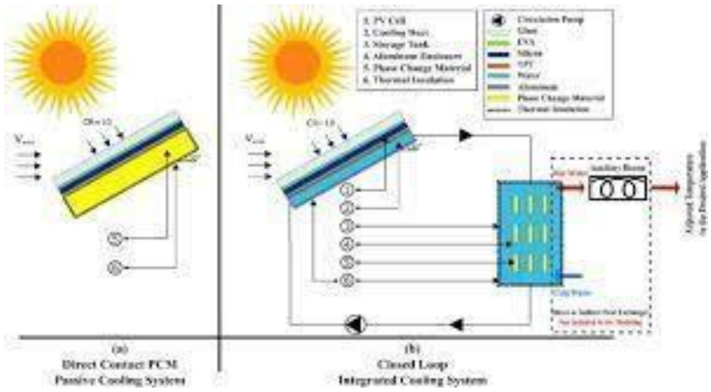
Hafiz Muhammad Ali conducted a recent study in the field of photoelectric refrigeration and confirmed its commitment to integrating print electronics into changing foods, as he found in recent years, there has been a growing interest among researchers in addressing the issue of declining photovoltaic Efficiency caused by high operating temperatures, particularly in hot climates. This article presents a comprehensive review of research conducted in the last five years on cooling techniques involving phase-change materials (PCMs), nanofluids, and their combined application to enhance efficiency.

Research indicates that passive cooling methods utilizing PCMs can lead to significant improvements in PV efficiency, with enhancements of up to 20% observed. The effectiveness of PCM-based cooling is more pronounced during summer months compared to winter. Incorporating fins inside PCM containers at the rear of PV panels improves heat conduction within the PCM, further enhancing cooling efficiency.

Recently, there has been a growing interest in composite PCMs for PV cooling due to their enhanced thermal conductivity. Additionally, using two PCMs with different melting points can result in better heat regulation and temperature uniformity across the PV surface. Studies suggest that combining passive and active cooling techniques can further reduce PV cell temperatures, resulting in increased efficiency and additional thermal power generation.

Integration of PCM with water-based hybrid PV systems has shown potential for improving PV efficiency by up to 32%. While nanofluid-based PV/T systems have demonstrated efficiency improvements of over 60%, combining PCM and nanofluid proves to be a more effective cooling approach than using either individually. Combining nanofluid with nano-PCMs can further enhance electrical power and efficiency.

Nanofluids also offer promise as spectral filters, requiring minimal thickness and allowing for tuning by adjusting nanoparticle concentrations. Finally, the environmental impacts and economic viability of these cooling techniques are discussed. Studies indicate that PV/PCM systems may become expensive and less feasible when operated as single junctions, with payback periods of up to 20 years. However, combining passive and active cooling methods can increase economic feasibility by reducing system size and cos.[20]



(a) Direct Contact PCM Passive Cooling System

(b) Closed Loop Integrated Cooling System

Figure 2-2 Integrative passive and active cooling system using PCM and nanofluid for thermal regulation of concentrated photovoltaic solar cells

3.2. COOLING USING NANOFLUIDS (Graphene/Water) AND PHASA CHANGE MATERIALS

Conducted by Ali Hassan et all. A study on thermal management and uniform temperature regulation of photovoltaic modules using a phase change hybrid nanomaterial system, where it was found that a continuous rise in the temperature of photovoltaic panels leads to a decrease in photovoltaic energy production. This study presents an experimental approach conducted outdoors in Taxila, Pakistan, with the aim of reducing the temperature of photovoltaic cells through the combined use of nanofluids (graphene/water) and phase change materials. The performance of this hybrid photovoltaic-thermal (PVT) system, including PV temperature, electrical efficiency, thermal efficiency, and overall efficiency, is compared with a PVT system integrated with phase change materials (PCM) using piped water and PV. / PCM system, conventional PV settings.

The effects of varying graphene nanoparticle size concentration and flow rates were also studied. Optimal performance was observed at a nanoparticle concentration of 0.1% and a flow rate of 40 L/min. The results indicate that the nanofluidic-based PVT/PCM system achieves maximum PV temperature reduction, with improvements in electrical efficiency over conventional PV systems of up to 23.9%.

Furthermore, the nanofluidic-based hybrid PVT/PCM system shows 17.5% higher thermal efficiency compared to its water-based counterpart, resulting in an overall efficiency improvement of 12%. These results confirm the superior performance of the hybrid PVT system integrated with nanofluids and PCM simultaneously.

The continuous increase in the temperature of photovoltaic (PV) panels results in a decline in PV electric power production. This research presents an experimental study conducted outdoors in Taxila, Pakistan, with the objective of reducing PV temperature by employing a combination of nanofluid (graphene/water) and phase change material (RT-35HC). The study evaluates the performance of this hybrid photovoltaic-thermal (PVT) system, assessing PV temperature, electrical efficiency, thermal efficiency, and overall efficiency. A comparative analysis is conducted with a PVT system incorporating phase change material (PCM) using water flowing through tubes, a PV/PCM system, and conventional PV setups.

The study also investigates the impact of varying volume concentrations (0.05%, 0.1%, 0.15%) of graphene nanoparticles and flow rates (20, 30, 40 LPM). Optimal performance is observed with a nanoparticle concentration of 0.1 vol% and a flow rate of 40 LPM. Results indicate that the nanofluid-based PVT/PCM system achieves the most significant reduction in PV temperature, with enhancements in electrical efficiency of up to 23.9% compared to conventional PV systems.

Moreover, the nanofluid-based hybrid PVT/PCM system exhibits a 17.5% higher thermal efficiency compared to its water-based counterpart, resulting in an overall efficiency improvement of 12%. These findings highlight the superior performance of the hybrid PVT system, which integrates nanofluid and PCM simultaneously.[21]

3.3. THE COOLING PROCESSES WERE TESTED POROUS MEDIA (gravel) WITH DIFFERENT POROSITY:

Researcher I. Masalha conducted a study on the electrical power production through photovoltaic panels, which has become essential due to the high demand for electrical power supply worldwide to cope with new technological developments. However, these PV cells are affected by the temperature rise on the back surface during their operation, which decreases their electrical power and reduces their performance. Therefore, it is crucial to keep the photovoltaic back surface temperature as low as possible. In this study, cooling processes using porous media (gravel) of different porosities, such as 0.35, 0.4, and 0.48, were tested at different flow rates. Accordingly, This study was divided into three scenarios :

a. In the first scenario, porous media with a porosity of 0.35 (case I) were compared with water case (case II) without any porosity and with an uncooled case (case III).
b. In the second scenario, three channels were filled with different porosities (i.e., 0.35, 0.4, and 0.48) (i.e., case I, case IV, case V) and compared with the uncooled case III.
c. In the third scenario, three channels filled with porous media of the same porosity of 0.35, but at different flow rates (i.e., 1 L/min, 2 L/min, and 3 L/min) (case a, case b, case c) were tested.

Based on the results, the lowest photovoltaic surface temperature was reduced by approximately 35.7%, while the power output increased by 9.4% at a volume flow rate of 3 L/min and a porosity of 0.35 (case c). Additionally, there was an agreement between the experimental and numerical results. Through mathematical equations, the effect of Nusselt number, Reynolds number, Prandtl number, and porosity on the heat transfer coefficient, as well as the effect of water entry velocity, porosity, and gravel diameter on pressure drop, were determined.[22]

3.4 AN EFFICIENT EFFICIENT PULSED - SPRAY WATER COOLING SESTEM FOR PHOTOVOLTAIC PANELS

The researcher A.Hadipour in this experiment, designed a water cooling system with intermittent spraying of solar panels with the aim of reducing water consumption and improving the efficiency of solar systems. The performance of solar panels cooled using this system was compared with solar panels cooled using a continuous spray cooling system, and those not cooled. The amount of electrical energy produced by the solar panels was measured in each case, using appropriate measuring devices. The amount of water consumed during the cooling process was also recorded in each case. Next, a cost analysis was performed to estimate the financial costs of each cooling system. The costs associated with operating the different systems were compared together with the potential benefits of each system.

The results showed that the intermittent spray cooling system is able to significantly increase the efficiency of solar panels and reduce water consumption compared to the traditional continuous spray cooling system. The financial analysis also showed that using an intermittent system can be economical and can significantly reduce the cost of producing electricity from solar panels. in this experiment, designed a water-cooling system with intermittent spraying of solar panels with the aim of reducing water consumption and improving the efficiency of solar systems. The performance of solar panels cooled using this system was compared with solar panels cooled using a continuous spray cooling system, and those not cooled.

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3.5. Indirect cooling of photovoltaic panels based on radiative cooling

Shuai Li et al. studied the indirect cooling of photovoltaic (PV) panels based on radiative cooling. Radiative cooling (RC) is a passive cooling technology used to cool photovoltaic (PV) panels without consuming energy or producing pollution. In previous studies, RC materials were used on top of PV panels to directly enhance the heat emission, which reduced the temperature, but this approach also reduced the panels' ability to absorb sunlight, resulting in a decrease in the power conversion efficiency (PCE). In this study, an indirect cooling system for PV panels based on RC was proposed, consisting of a PV module, an RC module, a cold storage module, and a piping system. The RC module was placed between adjacent PV panels, and the resulting cold energy was used to cool the panels through a water system. Experimental results showed that the system without a cold storage module reduced the average temperature of PV panels by 13.6 °C and 10.6 °C, respectively, in summer and autumn, resulting in an increase in the power conversion efficiency by 1.21% and 0.96%. After the application of the cold storage unit, the cold energy generated by the RC unit at night was stored for use during the day, reducing the average temperature of the photovoltaic panels by 17.8℃ and 16.6℃ in summer and autumn, and increasing the energy efficiency by 1.69% and 1.51%. In addition, the use of a protective cover and large-capacity water tank further enhances the efficiency of the system. The proposed system is expected to have an economic payback period of 8 years, and the photovoltaic power generation will increase by at least 2.8 billion kWh by 2050.[24]

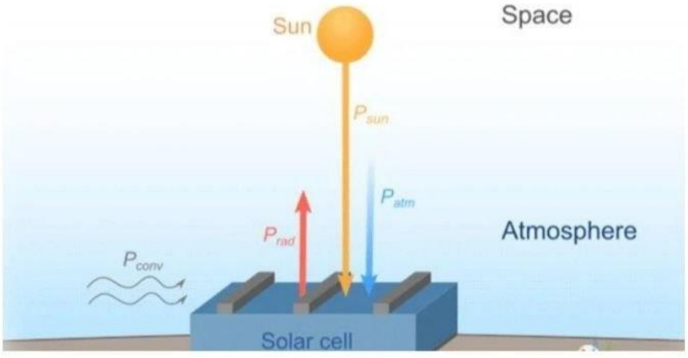

Figure 2-3: Schematic diagram showing radiative cooling technology on a photovoltaic cell.

CHAPETER 03

Experimental study

Of cooling

1. INTRODUCTION

In southern Algeria, the climate is very hot and dry, especially during July and August, with maximum temperatures sometimes rising to levels of up to 50°C in the afternoon. This extreme weather condition poses a major challenge, especially when it comes to the operation and maintenance of PV systems.

Under these harsh conditions, converting solar energy into electrical energy becomes a task of great importance, but it faces many challenges related to high temperatures and their impact on the efficiency of photovoltaic systems. The goal of this study is to search for technical solutions that contribute to improving the efficiency of solar energy conversion under these harsh weather conditions.

2. PRESENTATION OF THE TEST REGION

The experiments will be held outdoors next to the stadium located at the third university pole, Ouargla. The city of Ouargla is located in the southeast of Algeria and has an area of 163,233 square km^2. Ouargla is one of the hottest regions in the country. You have a distinct desert climate, where temperatures are both cold and hot. It is also less humid, contains less water, and has an annual wind speed of 3.70 m. Clear sun annually. It also enjoys a large amount of solar radiation annually, making it an ideal place for solar energy development. Experiments to evaluate the cooling effect of solar panels will be conducted during the period 05/21/2024.

3. EXPERIMENT DESCIRIPTION

The work presented in this thesis allows us to study the cooling of photovoltaic solar panels by wet burlap and geothermal. As is known, the temperature of the photovoltaic cell is an important factor affecting the electrical efficiency of the panel. To overcome this drawback, we did the following

As is known, geothermal cooling is considered a potential solution to the temperature problem of photovoltaic modules. From a certain depth, the temperature below the surface is constant throughout the year. Subsurface temperatures range between 10°C and 20°C at shallow depths of 5 to 15 meters.

In the experimental system, the system created by the research team in the field of hydrocarbons and energy transport within the framework of the doctoral thesis of the student B

Ali Oussama, is linked to the third pole of the University of Ouargla. This system is connected to a photoelectric cell for the purpose of cooling it, while the second photocell remains a reference for comparison between them.

The system consists of pipes buried at a depth of 2.5 Figure 3.2 meters, through which the air needed to cool the photovoltaic modules is circulated. The tubes form an S at the horizontal ground level. The pipes are made of polyvinyl chloride (PVC) and are 47 meters long and 0.11 meters in diameter, arranged separately from each other. With a distance between the two axes of 2 meters and 3 floors. Figure 3.1 represents the system used to cool photovoltaic panels. A variable flow extractor (50 Watt portable fan) is placed at the inlet of the system to ensure continuous air circulation as shown in Figure 3.3. While connecting the system port to the PV module to be cooled.

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Figure 3-1 Solar panel housing

Figure 3-2: Air distribution pipes

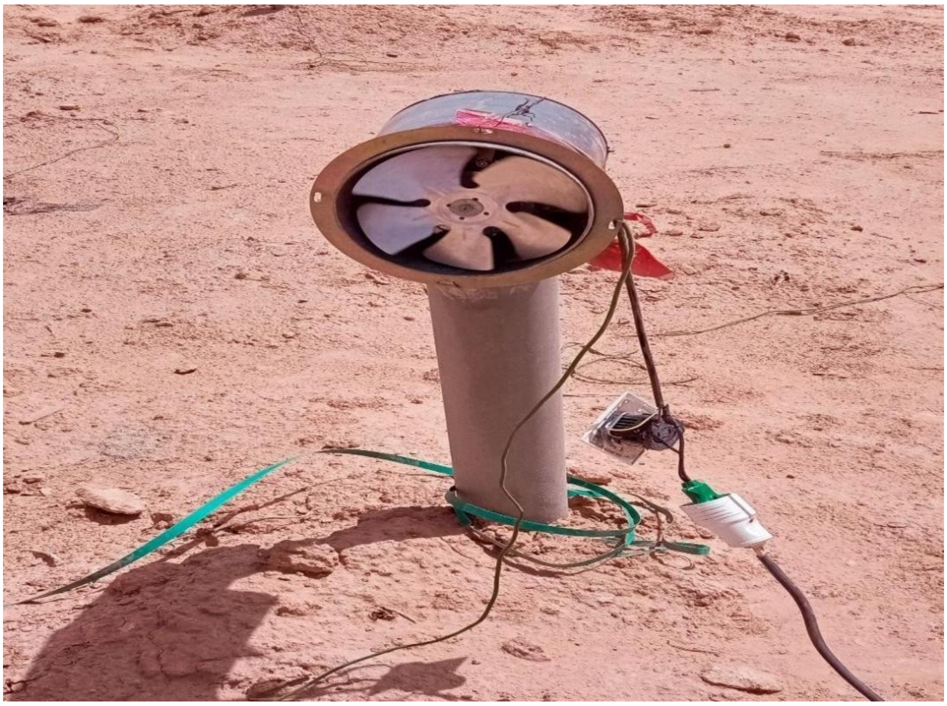

Figure 3-3: Air fan

4. THIRD DIFFERENT CHARACTERISTICS OF PHOTOVOLTAIC CELLS USED:

Two identical polycrystalline silicon PV modules with a maximum output power of 80 W were used in this study. One unit was connected to the proposed cooling system, and the second unit was kept for reference **(Figure3.5).** The units were installed next to the stadium located at the third pole of the University of Ouargla. Thus, the two units headed south with a constant inclination in latitude towards the city of Ouargla (31° 57'). The experiments were carried out during May 2024. Table 1 shows the specifications of polycrystalline photovoltaic modules.

Parameter	Specification
Technology	Polycrystalline
Maximum power (W)	80
Maximum voltage (V)	17.4
Maximum current (A)	4.61
Open circuit voltage (V)	22
Short circuit current (A)	4.85
Area(mm^2)	900 × 670

Table (1): represents details of the specifications of the various measuring devices used according to the technical data of the equipment manufacturers

5. DIFFERENT MEASURENT EQUIPMENT FOR AN EXPERIMENT:

The thermal and electrical characteristics of both the reference and test units (refrigerated) were monitored and measured using a variable resistor (PHYWE SE6) which is a load resistor and a digital multimeter (METEX ME-31) to measure the unit output power in terms of current and voltage.

Three K-type thermocouples were placed vertically at different positions on the back surface of each unit. To measure the operating temperature, the thermocouples were connected to a data logger (Keithley 2750) that transmitted the measurement data to the computer.

Weather parameters on the test days such as ambient temperature, solar radiation and wind speed were monitored and measured respectively using a K-type thermocouple, an LP02 thermometer and (Testo 425) hot-wire anemometer. Details of the specifications of the various measuring equipment used according to the technical data of the equipment manufacturers are given in Table 2.

Parameter	Instrument Model	Range	Accuracy
Solar irradiation	LP02 Pyranometer	0 – 2000 W/m^2	± 1.8 %
Temperatures	K-type thermocouples	-200 – 1260 °C	± 2 %
Wind velocity	Testo 425	0 – 20 m/s	± (0.03 m/s)
DC - Current	METEX ME-31	0.002 – 20 A	± (0.3 – 0.8 %)
DC - Voltage	METEX ME-31	0.2 – 200 V	± 0.05 %
Load resistor	PHYWE SE6	0 – 33 Ω	± 10 %

Table (2): represents the specifications of polycrystalline PV modules used under STC standard test conditions.

6. PREPARING THE COOLING SESTEM

Refrigeration is an old and effective method. It has been used for centuries for cooling Water and keep fruits and vegetables fresh, especially in remote and dry communities With high temperatures and lack of electricity. In this study, a passive cooling system was developed to reduce the unit size temperature in order to improve its efficiency. The proposed system relies on ground heat and a wet piece of burlap cloth attached directly to the back surface of the piece Loneliness. Burlap is a very rough and strong piece of cloth made from plant fibres; It's sustainable It is an environmentally friendly product and is usually used in the manufacture of burlap bags that are used to transport agricultural products and foodstuffs such as cotton, vegetables and coffee and pills. Figure 3.4 shows a sample of the burlap fabric used in this study.

Figure 3-4: Sample of the used burlap cloth.

Figure 3-5 : The board improved by roughness and geothermal

7. RESULTS AND DISCUSSIONS:

Éclairement	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00
Température	411	417	433	445	453	450	444	423	412

Table (3): a light beam in terms of time

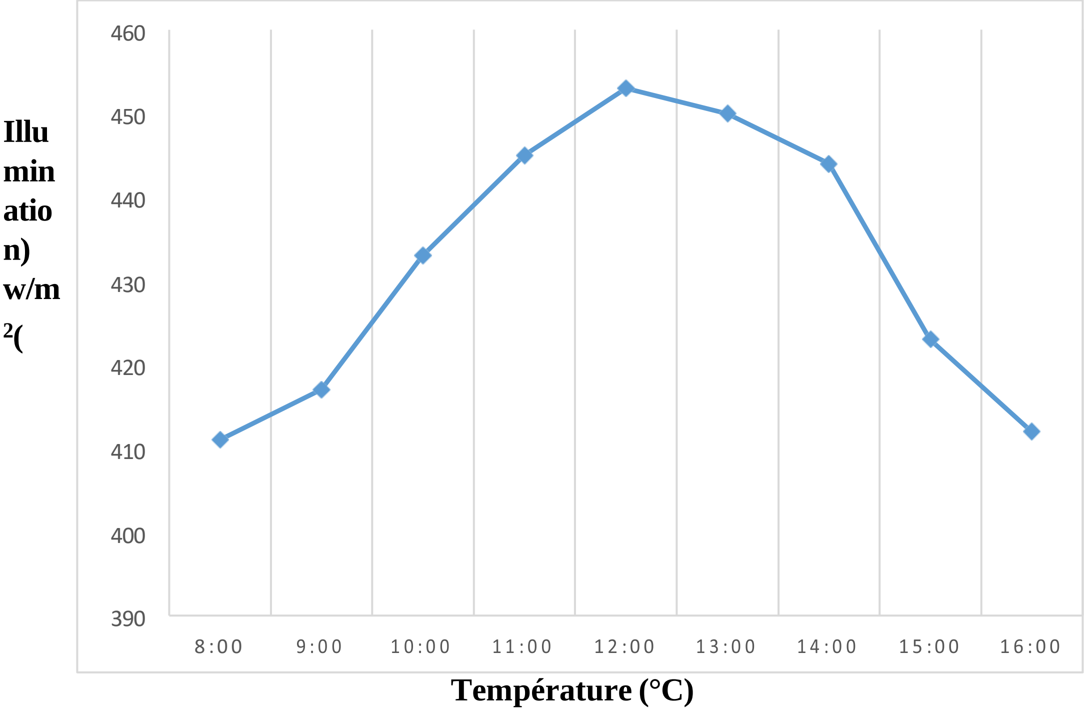

Figure 3-6: The curve of a light beam in terms of time

The curve represents light radiation as a function of time. We notice from the curve that as time increases, the amount of radiation increases, reaching a maximum value at 12 a.m. This is an indication that light radiation has a direct relationship with the sun, as shown. Once the sun sets, we notice a decrease in light radiation, and from this we conclude that the angle The sun affects the intensity of light received by the solar panel from radiation throughout the day.

Température	9:00	9:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00
T1	45.6	46.7	46;8	47.7	48.2	48.4	49.2	49.9	50.5
T'1	40.5	37.6	36.1	36.9	35.6	35.1	34.9	34.1	34.1

Table (4): The temperature of the bottom of the plate in relation to time

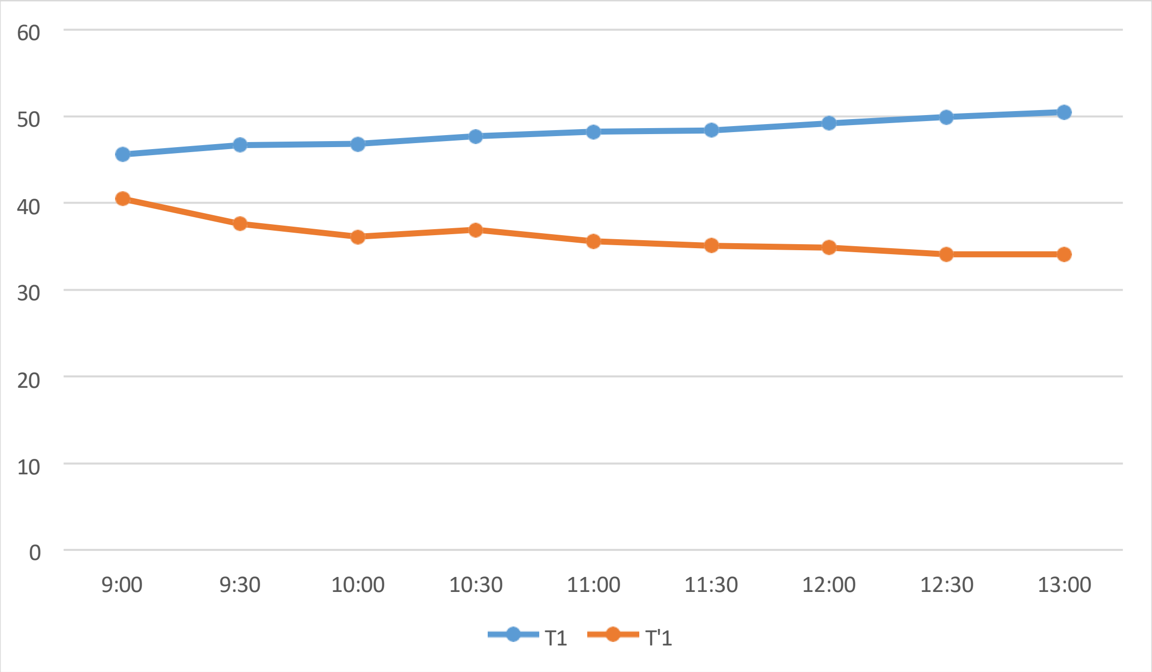

Figure 3-7: The temperature of the bottom of the plate in relation to time

The curve represents the temperature changes of the lower panels of normal and improved, T1 and T'1. In the first case, we notice an increase in temperature, and this is an indication of the panel’s temperature compared to the improved panel T’1. It also decreased significantly, and this is an indication that the cooling used in the experiment has a positive effect.

Température	9:00	9:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00
T2	48.7	48.4	50.8	50.6	51.1	49.8	50.4	55.2	56.5
T'2	47.9	47	43.4	42.5	40.9	40.5	40.6	35.9	35.6

Table (5): The temperature of the middle of the plate in terms of time

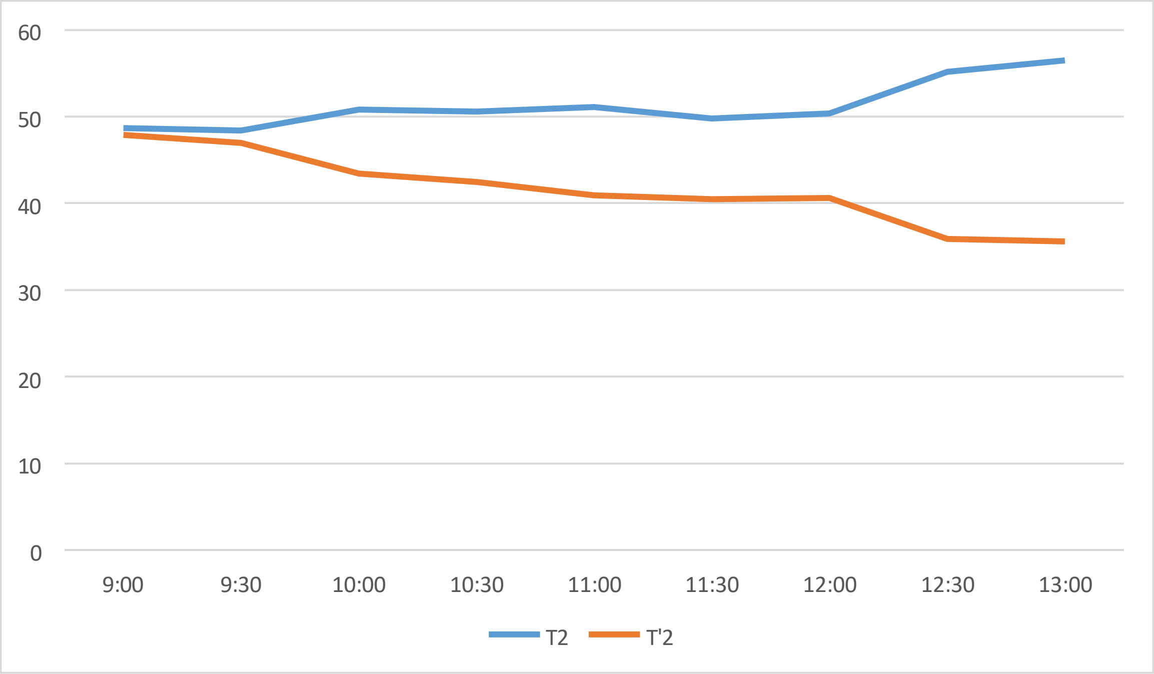

Figure 3-8: The temperature of the middle of the plate in terms of time

The curve represents the temperature changes between the normal and improved panels, T2 and T'2. We notice from the curve that the initial value was very close to its core, and this is an indication that the T'2 panel had not started cooling yet, but when 10 a.m. arrived, the wet Fiber and geothermal began working. When cooling the solar panel, we notice an increase in T2, and this is certain because it does not contain factors similar to T'2

Température	9:00	9:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00
T3	50.3	50.4	50.4	50.8	53.3	51.7	54.6	55.6	56.3
T'3	52.6	47.8	47.3	46.8	47.2	45.8	40.1	40.1	56.3

Table (6): TemperatureT3 above the plate in time

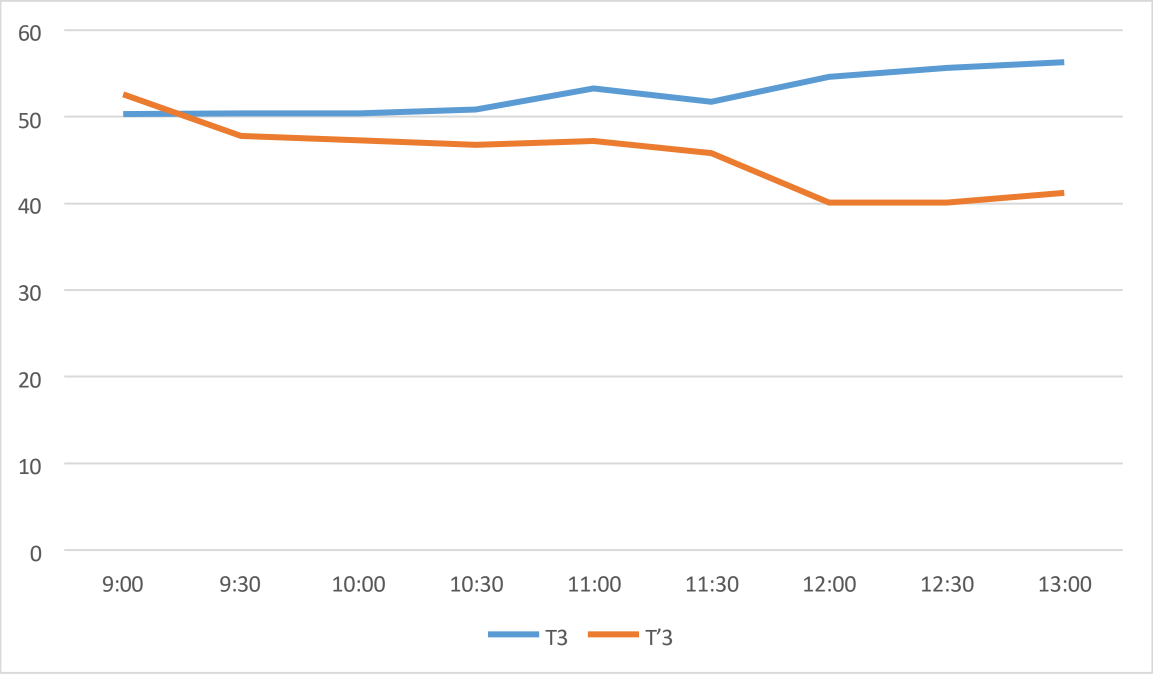

Figure 3-9: Temperature above the plate in time

The curve represents the temperature changes of the normal and enhanced plate, T3 and T'3. We notice from the curve that the average temperature is higher compared to the other curves, and this is because it is directly exposed to sunlight. However, the cooling used took some time.

8. A RESULT

The issue of cooling solar panels continues to interest researchers and specialists in the field of clean energy, due to the effect of high temperatures on reducing the efficiency of photovoltaic systems. By analyzing the following curves, we can notice that solar panels are clearly affected by heat, but the cooling used in the experiment resulted in a positive effect in different areas of the panel and to varying degrees.

There is a dynamic relationship between temperature and the amount of variable solar radiation reaching the panels during the day and in different seasons.

These changes directly affect the amount of energy that solar panels can generate. Studies indicate that increasing the temperature of solar panels above 25 degrees Celsius (the temperature at which they are tested) leads to a decrease in their productivity compared to the expected rate.

Conclusion:

Solar energy has been a vital source of renewable energy for humanity for decades. Researchers have proposed many strategies to harness this energy, but only photovoltaic (PV) technology has reached commercial scale and has been very successful in meeting renewable energy goals in many countries. The main disadvantage of photovoltaic systems is that an increase in the temperature of the photovoltaic module's solar cell beyond the minimum leads to a decrease in its electrical efficiency.

This paper discusses different cooling technologies responsible for reducing the cell temperature, which not only increases energy efficiency but also enables the collection of thermal energy that negatively affects the performance of the PV system. A brief study of photovoltaics showed that it is the most advanced and interesting of all renewable energy sources, thanks to the high potential of global solar energy, improvements in efficiency, and a significant decline in the cost of photovoltaic technologies.

However, there are several factors that affect the conversion efficiency of PV systems, and they can be divided into three main sections: photovoltaic cell technological factors, installation type factors, and environmental factors. In-depth bibliographic research has enabled us to obtain a general idea about the influence of environmental factors, especially heat in desert areas, on the efficiency and robustness of PV conversion systems.

The work presented in this thesis is based on the experimental study and evaluation of the effect of weather conditions on the performance of photovoltaic conversion systems installed in arid regions, especially in southern Algeria. It also contributes to improving the efficiency of the photovoltaic systems installed in these areas. On the performance of crystalline photovoltaic modules installed experimentally in the desert environment.[1]

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