

**SUDAN UNIVERSITY OF
SCIENCE AND TECHNOLOGY
COLLEGE OF GRADUATE STUDIES**



**Comparison between the parabolic and dish solar
collectors by using MATLAB**

**مقارنة بين المجمع الشمسي ذو القطع المكافئ ومجمع الطبق الشمسي
بإستخدام برنامج الماتلاب**

**A Thesis Submitted in Partial Fulfillment of the Degree of
M.Sc. in Program of Mechatronics Engineering**

**BY
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MAY 2016

بسم الله الرحمن الرحيم

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الآيه

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ
وَ (الشَّمْسُ تَجْرُ لِيُمَدِّقَ لَهَا أَذِلَّةً لِلزُّعُرِ يَزِيدُ
الْعَالِمِينَ {38} الْقَمَرَ قَدَرًا نَاهُمْ نَازِلًا حَتَّىٰ عَلَكَ الْعُرُّ جُودًا
الْقَدِيمِ {39} الشَّمْسُ يُنْبَغِي لَهَا أَنْ تُدْرِكَ الْقَمَرَ وَلَا اللَّيْلُ سَابِقُ
النَّهَارِ وَ كُلُّ فِي فَلْيَسْجُدُوا {40})

صدق الله العظيم
سورة يس: الايات (38-40)

DEDICATIONS

To my parents from whom I own my success and progress.

My Mother & My Father

To My Wife

To My Brothers

To My Sisters

To My Friends

ACKNOWLEDGEMENT

Firstly, I thank Almighty God (Allah) for guidance and help and our beloved prophet Mohamed peace be upon him. Deep affection is especially due to my parents who supported and encouraged me throughout my study.

*I express my sincere appreciations and thanks to my supervisor **Dr. Elhadi Badawi Mahgoub** for his support, sustained interest, smart supervision, tremendous encouragement and constructive criticisms for the completion of this work.*

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Abstract:

As a result of the anticipated shortage of traditional sources of energy and environmental problems caused by it, solar energy is considered the most important alternative energy, which is renewable and exploited, which is not subjected to economic considerations and just need huge machines to collect radiation or using concentrated solar collectors. The aim of the study is to compare the solar dish collector and parabolic solar collector and choosing the best to heat the furnace oil.

In this study MATLAB program have been used to calculate the dimensions and efficiency of solar dish collector and parabolic solar collector for steam quantity of 2000Kg/hr. at 10bar pressure and temperature of 200C° for Nile cement factory in the city of rabak.

The results obtained showed that the length of a solar parabolic collector of diameter 3m is 581.354m with efficiency of 66.67% and diameter of a solar dish collector is 41.762m with efficiently of 66.67% thus the best solar collector is the solar dish.

المستخلص

نتيجة للنقص المتوقع للمصادر التقليدية للطاقة والمشاكل التي تسببها للبيئة تعتبر الطاقة الشمسية من الطاقات البديلة الأكثر أهمية , والقابلة للتجديد حيث ان استغلالها ليس خاضع للاعتبارات الاقتصادية وتحتاج فقط الى اجهزه ضخمة لتجميع الاشعاع أو استخدام المجمعات الشمسية المركزة

الهدف من الدراسة هو المقارنة بين المجمع الشمسي ذو القطع المكافئ ومجمع الطبق الشمسي وإختيار الأفضل لتسخين الفيرنس.

في هذه الدراسة تم إستخدام برنامج الماتلاب في حساب أبعاد وكفاءة المجمع الشمسي ذو القطع المكافئ ومجمع الطبق الشمسي لكمية بخار 2000Kg/hr. عند ضغط 10bar ودرجة حرارة 200C° لمصنع النيل للأسمنت بمدينة ربك .

كانت النتائج المتحصل عليها أن الطول للمجمع الشمسي ذو القطع المكافئ لقطر 3m هو 581.354m وكفاءته 66.67% وقطر مجمع الطبق الشمسي هو 41.762m بكفاءة 66.67% وبذلك يكون أفضل مجمع شمسي هو الطبق الشمسي.

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CHAPTER ONE

CHAPTER ONE

1. INTRODUCTION

1.1 Background

In today's climate of growing energy needs and increasing environmental concern, alternatives to the use of non-renewable and polluting fossil fuels have to be investigated. One such alternative is solar energy.

Solar energy is simply the energy produced directly by the sun and collected elsewhere, normally the Earth. The sun creates its energy through a thermonuclear process that converts about 650, 000,000 tons of hydrogen to helium every second. The process creates heat and electromagnetic radiation. The heat remains in the sun and is instrumental in maintaining the thermonuclear reaction. The electromagnetic radiation (including visible light, infra-red light, and ultra-violet radiation) streams out into space in all directions.

Only a very small fraction of the total radiation produced reaches the Earth. The radiation that does reach the Earth is the indirect source of nearly every type of energy used today. The exceptions are geothermal energy, and nuclear fission and fusion. Even fossil fuels owe their origins to the sun; they were once living plants and animals whose life was dependent upon the sun.

Much of the world's required energy can be supplied directly by solar power. More still can be provided indirectly. The practicality of doing so will be examined, as well as the benefits and drawbacks. In addition, the use of solar energy is currently applied will be noted.

Mathematical modeling and computer simulation recently has become very common. Arithmetical models save money, time and labor. Models are tools to design of solar collector parabolic. The best model should provide predicted values close to actual values.

1.2 Problem Formulation:

Study a parabolic solar collector and dish solar collector to produce steam for heating the furnace oil in the Nail Cement factory for utilization of solar energy in Sudan.

1.3 Scope:

Study a parabolic solar collector and dish solar collector and determine the best design in terms of space and efficiency and the temperature of the fluid entering to heating the furnace oil in the Nail Cement factory.

1.4 Objectives:

- To compare between a parabolic solar collector and dish solar collector by the required space and efficiency.
- To calculate by MATLAB program to ensure appropriate design to produce the energy need to produce 2 tons of steam at 10bar pressure and temperature of 200C° for heating the furnace oil in the Nail Cement factory.
- To calculate the dimensions of the best solar collector.

1.5 Methodology:

Using the available data of solar energy and implementing the equation of parabolic solar collector and dish solar collector to predict the dimensions and performance for the required capacity.

1.6 Overview of the Thesis:

This Chapter has presented an introduction of solar energy and Problem formulation, Scope objectives, Methodology and Overview of the thesis, Chapter two presents a literature a background of the problem, Chapter three presents a solar radiation and Solar Parameters, Chapter four presents a methodology using MATLAB program, Chapter five presents the results, Chapter six conclusion recommendation.

CHAPTER TWO

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Background:

The sun is a sphere of intensely hot gaseous matter with a diameter of 1.39×10^9 m. The solar energy strikes our planet in merely an 8 min and 20 s after leaving the giant furnace, the sun which is 1.5×10^{11} m away. The sun has an effective blackbody temperature of 5762 K. The temperature in the central region is much higher and it is estimated at 8×10^6 to 40×10^6 K. In effect the sun is a continuous fusion reactor in which hydrogen is turned into helium. The sun's total energy output is 3.8×10^{20} MW which is equal to 63 MW/m^2 of the sun's surface. This energy radiates outwards in all directions. Only a tiny fraction, 1.7×10^{14} kW, of the total radiation emitted is intercepted by the earth. However, even with this small fraction it is estimated that 30 min of solar radiation falling on earth is equal to the world energy demand for one year ^[1].

Man realized that a good use of solar energy is in his benefit, from the prehistoric times. The Greek historian Xenophon in his 'memorabilia' records some of the teachings of the Greek Philosopher Socrates (470–399 BC) regarding the correct orientation of dwellings in order to have houses which were cool in summer and warm in winter.

Since prehistory, the sun has dried and preserved man's food. It has also evaporated sea water to yield salt. Since man began to reason, he has recognized the sun as a motive power behind every natural phenomenon. This is why many of the prehistoric tribes considered Sun as 'God'. Many scripts of ancient Egyptian that the Great Pyramid, one of the man's greatest engineering achievements, was built as a stairway to the sun ^[2].

Basically, all the forms of energy in the world as we know it are solar in origin. Oil, coal, natural gas and woods were originally produced by photosynthetic processes, followed by complex chemical reactions in which decaying vegetation was subjected to very high temperatures and pressures over a long period of time ^[1]. Even the wind and tide energy have a solar origin since they are caused by differences in temperature in various regions of the earth. The greatest advantage of solar energy as compared with other forms of energy is that it is clean and can be supplied without any environmental pollution. Over the past century fossil fuels have

provided most of our energy because they are much cheaper and more convenient than energy from alternative energy sources, and until recently environmental pollution has been of little concern.

In addition to the thousands of ways in which the sun's energy has been used by both nature and man through time, to grow food or dry clothes, it has also been deliberately harnessed to perform a number of other jobs. Solar energy is used to heat and cool buildings (both active and passive), to heat water for domestic and industrial uses, to heat swimming pools, to power refrigerators, to operate engines and pumps, to desalinate water for drinking purposes, to generate electricity, for chemistry applications, and many more. The objective of this research is to present the various types of collectors used to harness solar energy, their thermal analysis and performance, and a review of applications. There are many alternative energy sources which can be used instead of fossil fuels. The decision as to what type of energy source should be utilized must, in each case, be made on the basis of economic, environmental and safety considerations. Because of the desirable environmental and safety aspects it is widely believed that solar energy should be utilized instead of other alternative energy forms, even when the costs involved are slightly higher.

2.2 Energy Related Environmental Problems:

Energy is considered a prime agent in the generation of wealth and a significant factor in economic development. The importance of energy in economic development is recognized universally and historical data verify that, there is a strong relationship between the availability of energy and economic activity. Although at the early 70s, after the oil crisis, the concern was on the cost of energy, during the past two decades, the risk and reality of environmental degradation have become more apparent. The growing evidence of environmental problems is due to a combination of several factors since the environmental impact of human activities has grown dramatically. This is due to the increase of the world population, energy consumption and industrial activities. Achieving solutions to environmental problems that humanity faces today requires long-term potential actions for sustainable development. In this respect, renewable energy resources appear to be one of the most efficient and effective solutions.

A few years ago, most environmental analysis and legal control instruments concentrated on conventional pollutants such as sulphur dioxide (SO₂), nitrogen oxides (NO_x), particulates, and carbon monoxide (CO). Recently however, environmental concern has extended to the control of hazardous air pollutants, which are usually toxic chemical substances which are harmful even in small doses, as well as to other globally significant pollutants such as carbon dioxide (CO₂). Additionally, developments in industrial processes and structures have led to new environmental problems ^[3].

Pollution depends on energy consumption. Today the world daily oil consumption is 76 million barrels. Despite the well-known consequences of fossil fuel combustion on the environment, this is expected to increase to 123 million barrels per day by the year 2020^[4]. There are a large number of factors which are significant in the determination of the future level of the energy consumption and production. Such factors include population growth, economic performance, consumer tastes and technological developments. Furthermore, governmental policies concerning energy and developments in the world energy markets will certainly play a key role in the future level and pattern of energy production and consumption.

2.3 Renewable Energy Technologies:

Renewable energy technologies produce marketable energy by converting natural phenomena into useful forms of energy. These technologies use the sun's energy and its direct and indirect effects on the earth (solar radiation, wind, falling water and various plants, i.e. biomass), gravitational forces (tides), and the heat of the earth's core (geothermal) as the resources from which energy is produced. These resources have massive energy potential, however, they are generally diffused and not fully accessible, most of them are intermittent, and have distinct regional variability's. These characteristics give rise to difficult, but solvable, technical and economical challenges. Nowadays, significant progress is made by improving the collection and conversion efficiencies, lowering the initial and maintenance costs, and increasing the reliability and applicability.

A worldwide research and development in the field of renewable energy resources and systems is carried out during the last two decades. Energy conversion

systems that are based on renewable energy technologies appeared to be cost effective compared to the projected high cost of oil.

Furthermore, renewable energy systems can have a beneficial impact on the environmental, economic, and political issues of the world.

By applying a renewable energy intensive scenario the global consumption of renewable sources by 2050 would reach 318 exajoules ^[5].

The benefits arising from the installation and operation of renewable energy systems can be distinguished into three categories; energy saving, generation of new working posts and the decrease of environmental pollution.

The energy saving benefit derives from the reduction in consumption of the electricity and/or diesel which are used conventionally to provide energy. This benefit can be directly translated into monetary units according to the corresponding production or avoiding capital expenditure for the purchase of imported fossil fuels. Another factor which is of considerable importance in many countries is the ability of renewable energy technologies to generate jobs. The penetration of a new technology leads to the development of new production activities contributing to the production, market distribution and operation of the pertinent equipment. Specifically in the case of solar energy collector's job creation mainly relates to the construction and installation of the collectors.

2.4 History of Solar Energy:

The idea of using solar energy collectors to harness the sun's power is recorded from the prehistoric times when at 212 BC the Greek scientist/physician Archimedes devised a method to burn the Roman fleet. Archimedes reputedly set the attacking Roman fleet afire by means of concave metallic mirror in the form of hundreds of polished shields; all reflecting on the same ship ^[1].

The Greek historian Plutarch (AD 46–120) referred to the incident saying that the Romans, seeing that indefinite mischief overwhelmed them from no visible means, began to think they were fighting with the gods. The basic question was whether or not Archimedes knew enough about the science of optics to device a simple way to concentrate sunlight to a point where ships could be burned from a distance. Archimedes had written a book "On burning Mirrors" but no copy has survived to give evidence ^[6].

Eighteen hundred years after Archimedes, Athanasius Kircher (1601–1680) carried out some experiments to set fire to a woodpile at a distance in order to see whether the story of Archimedes had any scientific validity but no report of his findings survived ^[6].

Amazingly, the very first applications of solar energy refer to the use of concentrating collectors, which are by their nature (accurate shape construction) and the requirement to follow the sun, more ‘difficult’ to apply. During the 18th century, solar furnaces capable of melting iron, copper and other metals were being constructed of polished-iron, glass lenses and mirrors. The furnaces were in use throughout Europe and the Middle East. One furnace designed by the French scientist Antoine Lavoisier, attained the remarkable temperature of 1750°C. The furnace used a 1.32 m lens plus a secondary 0.2 m lens to obtain such temperature which turned out to be the maximum achieved by man for one hundred years.

During the 19th century the attempts to convert solar energy into other forms based upon the generation of low- pressure steam to operate steam engines. August Mouchot pioneered this field by constructing and operating several solar-powered steam engines between the years 1864 and 1878^[6].

Evaluation of one built at Tours by the French government showed that it was too expensive to be considered feasible. Another one was set up in Algeria. In 1875, Mouchot made a notable advance in solar collector design by making one in the form of a truncated cone-reflector. Mouchot’s collector consisted of silver-plated metal plates and had a diameter of 5.4 m and a collecting area of 18.6 m². The moving parts weighed 1400 kg.

Abel Pifre was a contemporary of Mouchot who also made solar engines. Pifre’s solar collectors were parabolic reflectors made of very small mirrors. In shape they looked rather similar to Mouchot’s truncated cones. In 1901 A.G. Eneas installed a 10 m diameter focusing collector which powered a water pumping apparatus at a California farm. The device consisted of a large umbrella like structure open and inverted at an angle to receive the full effect of sun’s rays on the 1788 mirrors which lined the inside surface. The sun’s rays were concentrated at a focal point where the boiler was located. Water within the boiler was heated to produce steam which in turn powered a conventional compound engine and centrifugal pump.

In 1904 a Portuguese priest, Father Himalaya, constructed a large solar furnace. This was exhibited at the St Louis World's fair. This furnace appeared quite modern in structure, being a large, off-axis, parabolic horn collector [6].

In 1912 Shuman, in collaboration with C.V. Boys, undertook to build the world's largest pumping plant in Egypt. The system was placed in operation in 1913 and it was using long parabolic cylinders to focus sunlight onto a long absorbing tube. Each cylinder was 62 m long, and the total area of the several banks of cylinders was 1200 m². The solar engine developed as much as 37–45 kW continuously for a 5 h period. Despite the plant's success, it was completely shut down in 1915 due to the onset of World War I and cheaper fuel prices.

During the last 50 years many variations were designed and constructed using focusing collectors as a means of heating the transfer or working fluid which powered mechanical equipment. The two primary solar technologies used are the central receivers and the distributed receivers employing various point and line-focus optics to concentrate sunlight. Central receiver systems use fields of heliostats (two-axis tracking mirrors) to focus the sun's radiant energy onto a single tower-mounted receiver. Distributed receiver technology includes parabolic dishes, Fresnel lenses, parabolic troughs, and special bowls. Parabolic dishes track the sun in two axes and use mirrors to focus radiant energy onto a point-focus receiver. Troughs and bowls are line-focus tracking reflectors that concentrate sunlight onto receiver tubes along their focal lines. Receiver temperatures range from 100°C in low-temperature troughs to close 1500 °C in dish and central receiver systems [5].

Another area of interest, the hot water and house heating appeared in the mid-1930s, but gained interest in the last half of the 40s. Until then millions of houses were heated by coal burn boilers. The idea was to heat water and feed it to the radiator system that was already installed.

The manufacture of solar water heaters (SWH) began in the early 60s. The industry of SWH expanded very quickly in many countries of the world. Typical SWH in many cases are of the thermo syphon type and consist of two flat-plate solar collectors having an absorber area between 3 and 4 m², a storage tank with capacity between 150 and 180 l and a cold water storage tank, all installed on a suitable frame. An auxiliary electric immersion heater and/or a heat exchanger, for central heating assisted hot water production, are used in winter during periods of low solar insolation. Another important type of SWH is the forced circulation type. In this

system only the solar panels are visible on the roof, the hot water storage tank is located indoors in a plant room and the system is completed with piping, pump and a differential thermostat. Obviously, this latter type is more appealing mainly due to architectural and aesthetic reasons, but also more expensive especially for small-size installations ^[7].

2.5 Solar Energy in Sudan:

Sudan is an agricultural country with fertile land, plenty of water resources, livestock, forestry resources and agricultural residues. Energy is one of the key factors for the economic development in Sudan. An overview of the energy situation in Sudan is given with reference to the end uses and regional distribution. Energy sources are divided into two main types; conventional energy (biomass, petroleum products and electricity) and nonconventional energy (solar, wind, hydro, etc.). Sudan possesses a relatively high abundance of solar radiation, moderate wind speeds, hydro and biomass energy resources. Application of new and renewable sources of energy available in Sudan is now a major issue in the future energy strategic planning. Sudan has a long history of meeting its energy needs through renewables and the portfolio is broad and diverse, owing in part to the country's wide range of climates and landscapes ^[8]. Like many of the African leaders in renewable energy utilization, Sudan has a well-defined commitment to continue research, development and implementation of new technologies. Sustainable low carbon energy scenarios for the new century emphasize the untapped potential of renewable resources. Rural areas of Sudan can benefit from this transition. The increased availability of reliable and efficient energy services stimulates new development alternatives. It is concluded that renewable environmentally friendly energy must be encouraged and demonstrated by full scale plant especially for use in remote rural areas ^[9].

2.6 Solar Collectors:

Solar energy collectors are special kind of heat exchangers that transform solar radiation energy to internal energy of the transport medium. The major component of any solar system is the solar collector. This is a device which absorbs the incoming solar radiation, converts it into heat, and transfers this heat to a fluid (usually air, water, or oil) flowing through the collector. The solar energy thus collected is carried from the circulating fluid either directly to the hot water or space

conditioning equipment or to a thermal energy storage tank from which can be drawn for use at night and/or cloudy days.

There are basically two types of solar collectors: no concentrating or stationary and concentrating. A no concentrating collector has the same area for intercepting and for absorbing solar radiation, whereas a sun-tracking concentrating solar collector usually has concave reflecting surfaces to intercept and focus the sun's beam radiation to a smaller receiving area, thereby increasing the radiation flux.

A large number of solar collectors are available in the market. A comprehensive list is shown in Table (2.1).

Table (2.1) Solar Energy Collectors ^[5].

Motion	Collector	Absorber type	Concentration ratio	Indicative temperature range (°C)
Stationary	Flat plate collector (FPC)	Flat	1	30 – 80
	Compound parabolic collector	Tubular	1 – 5	60 – 240
Single-axis tracking	Linear Fresnel reflector (LFR) Parabolic collector (PTC) Cylindrical trough collector (CTC)	Tubular	5 – 15	60 – 300
		Tubular	10 – 40	60 – 250
		Tubular	15 – 45	60 – 300
		Tubular	10 – 50	60 – 300
Two-axes tracking	Parabolic dish reflector(PDR)	Point	100 – 1000	100 – 500
	Heliostat field collector(HFC)	Point	100 – 1500	150 – 2000

2.6.1 Stationary Collectors:

Solar energy collectors are basically distinguished by their motion, i.e. stationary, single axis tracking and two axes tracking, and the operating temperature. Initially, the stationary solar collectors are examined. These collectors are permanently fixed in position and do not track the sun. Two types of collectors fall in this category:

- i. Flat plate collectors (FPC);
- ii. Stationary compound parabolic collectors (CPC);

2.6.1.1 Flat-Plate Collectors (FPC):

A typical flat-plate solar collector is shown in Figure (2.1).

When solar radiation passes through a transparent cover and impinges on the blackened absorber surface of high absorptivity, a large portion of this energy is absorbed by the plate and then transferred to the transport medium in the fluid tubes to be carried away for storage or use. The underside of the absorber plate and the side

of casing are well insulated to reduce conduction losses. The liquid tubes can be welded to the absorbing plate, or they can be an integral part of the plate. The liquid tubes are connected at both ends by large diameter header tubes.

The transparent cover is used to reduce convection losses from the absorber plate through the restraint of the stagnant air layer between the absorber plate and the glass. It also reduces radiation losses from the collector as the glass is transparent to the short wave radiation received by the sun but it is nearly opaque to long-wave thermal radiation emitted by the absorber plate (greenhouse effect).

FPC is usually permanently fixed in position and require no tracking of the sun. The collectors should be oriented directly towards the equator, facing south in the northern hemisphere and north in the southern. The optimum tilt angle of the collector is equal to the latitude of the location with angle variations of 10–15° more or less depending on the application.

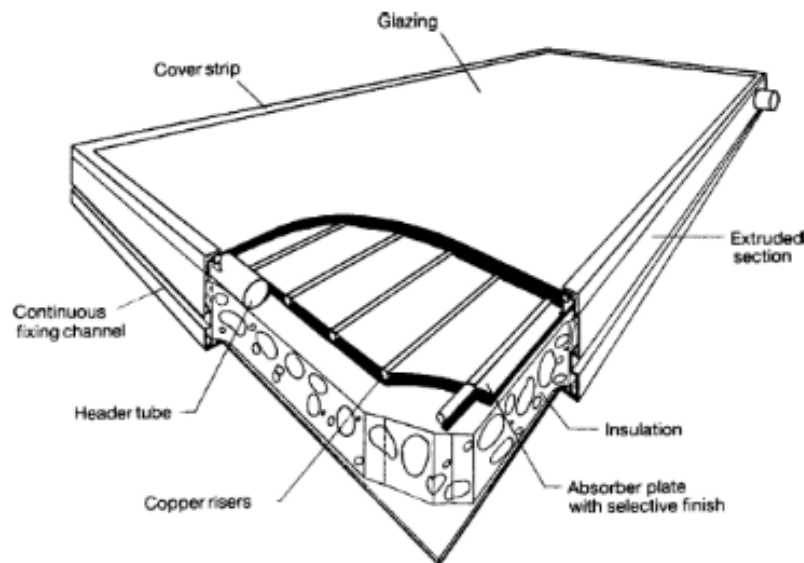


Figure (2.1) Pictorial View of a Flat-Plate Collector

2.6.1.2 Compound Parabolic Collectors (CPC):

CPC are non-imaging concentrators. These have the capability of reflecting to the absorber all of the incident radiation within wide limits. Their potential as collectors of solar energy was pointed out by Winston. The necessity of moving the concentrator to accommodate the changing solar orientation can be reduced by using a trough with two sections of a parabola facing each other, as shown in Figure (2.2).

Compound parabolic concentrators can accept incoming radiation over a relatively wide range of angles. By using multiple internal reflections, any radiation that is entering the aperture, within the collector acceptance angle, finds its way to the absorber surface located at the bottom of the collector. The absorber can take a variety of configurations.

It can be cylindrical as shown in Figure (2.2) or flat. In the CPC the lower portion of the reflector (AB and AC) is circular, while the upper portions (BD and CE) are parabolic. As the upper part of a CPC contribute little to the radiation reaching the absorber, they are usually truncated thus forming a shorter version of the CPC, which is also cheaper. CPCs are usually covered with glass to avoid dust and other materials from entering the collector and thus reducing the reflectivity of its walls.

These collectors are more useful as linear or trough-type concentrators ^[10].

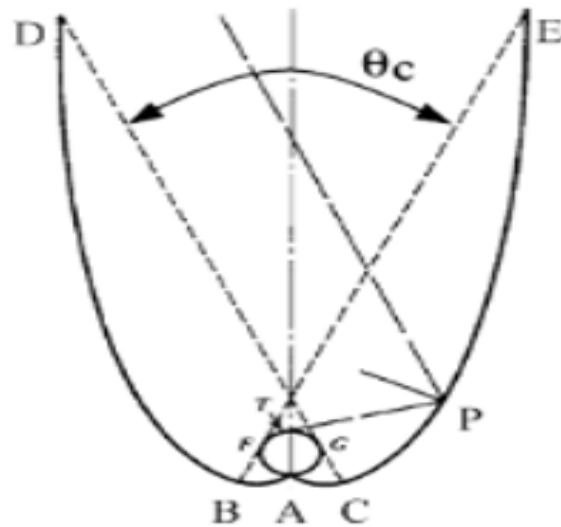


Figure (2.2) Schematic Diagram of a Compound Parabolic Collector

2.7 Concentrating Collectors:

Concentrating, or focusing, collectors intercept direct radiation over a large area and focus it onto a small absorber area. These collectors can provide high temperatures more efficiently than flat-plate collectors, since the absorption surface area is much smaller. However, diffused sky radiation cannot be focused onto the absorber. Most concentrating collectors require mechanical equipment that

constantly orients the collectors toward the sun and keeps the absorber at the point of focus. Therefore; there are many types of concentrating collectors ^[11].

2.7.1 Types of Concentrating Collectors:

There are four basic types of concentrating collectors:

- Parabolic trough system
- Parabolic dish
- Power tower
- Stationary concentrating collectors

2.7.1.1 Parabolic Trough System:

Parabolic troughs are devices that are shaped like the letter “u”.The troughs concentrate sunlight onto a receiver tube that is positioned along the focal line of the trough. Sometimes a transparent glass tube envelops the receiver tube to reduce heat loss ^[12].

Their shapes are like letter “u” as shown Figure (2.3) below.

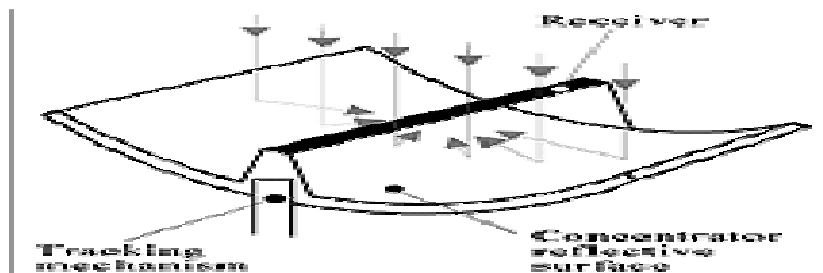


Figure (2.3)Crossection of Parabolic Trough.

The parabolic trough sytem is shown in the Figure (2.4) below.



Figure (2.4)Parabolic Trough System.

Parabolic troughs often use single-axis or dual-axis tracking.

The below Figure (2.5) shows one axis tracking parabolic trough with axis oriented E-W.

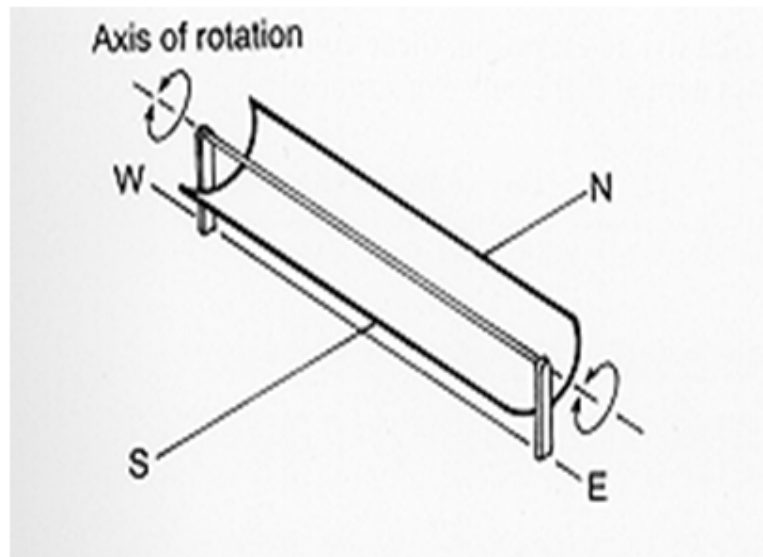


Figure (2.5) One Axis Tracking Parabolic Trough with Axis Oriented E-W.

The below Figure (2.6) shows two axis tracking concentrator.

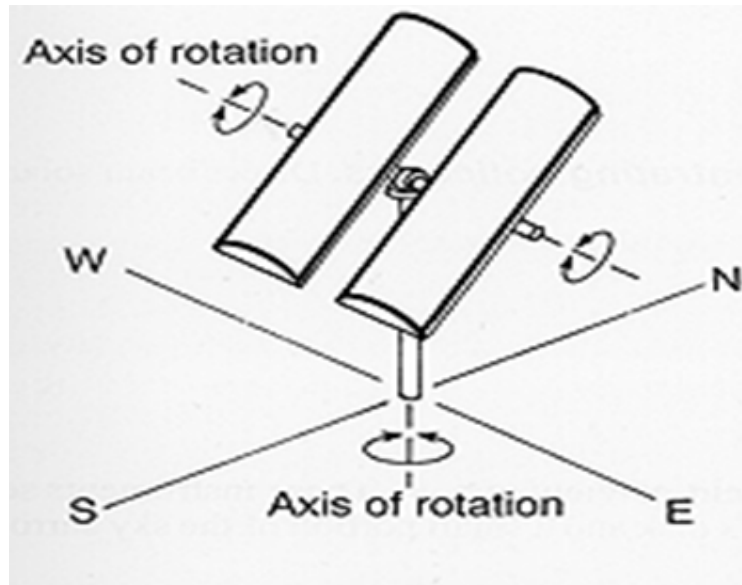


Figure (2.6) Two Axis Tracking Concentrator .

Temperatures at the receiver can reach 400 °C and produce steam for generating electricity. In California, multi-megawatt power plants were built using parabolic troughs combined with gas turbines ^[12].

Parabolic trough combined with gas turbines is shown Figure (2.7) below.



Figure (2.7) Parabolic Trough Combined With Gas Turbines .

Cost projections for trough technology are higher than those for power towers and dish/engine systems due in large part to the lower solar concentration and hence lower temperatures and efficiency. However with long operating experience, continued technology improvements, and operating and maintenance cost reductions, troughs are the least expensive, most reliable solar thermal power production technology for near-term^[13].

2.7.1.2 Parabolic Dish Systems:

A parabolic dish collector is similar in appearance to a large satellite dish, but has mirror-like reflectors and an absorber at the focal point. It uses a dual axis sun tracker^[12].

The below Figure (2.8) shows crosssection of parabolic dish.

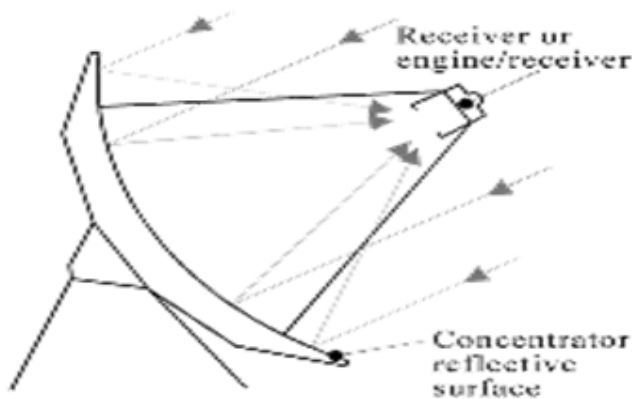


Figure (2.8) Crosssection of Parabolic Dish.

The Parabolic dish collector is shown in the below Figure (2.9).



Figure (2.9) Parabolic Dish Collector With a Mirror-like Reflectors And an absorber at the focal point [Courtesy of SunLabs - Department of Energy] .

A parabolic dish system uses a computer to track the sun and concentrate the sun's rays onto a receiver located at the focal point in front of the dish. In some systems, a heat engine, such as a Stirling engine, is linked to the receiver to generate electricity. Parabolic dish systems can reach 1000 °C at the receiver, and achieve the highest efficiencies for converting solar energy to electricity in the small-power capacity range^[12].

The below Figure (2.10) shows the solar dish Stirling engine.



Figure (2.10) Solar Dish Stirling Engine .

Engines currently under consideration include Stirling and Brayton cycle engines. Several prototype dish/engine systems, ranging in size from 7 to 25 kW have been deployed in various locations in the USA. High optical efficiency and low startup losses make dish/engine systems the most efficient of all solar technologies.

A Stirling engine/parabolic dish system holds the world's record for converting sunlight into electricity. In 1984, a 29% net efficiency was measured at Rancho Mirage, California ^[13].

2.7.1.3 Power Tower System:

A heliostat uses a field of dual axis sun trackers that direct solar energy to a large absorber located on a tower. To date the only application for the heliostat collector is power generation in a system called the power tower ^[12].

The below Figure (2.11) shows the Power tower system.

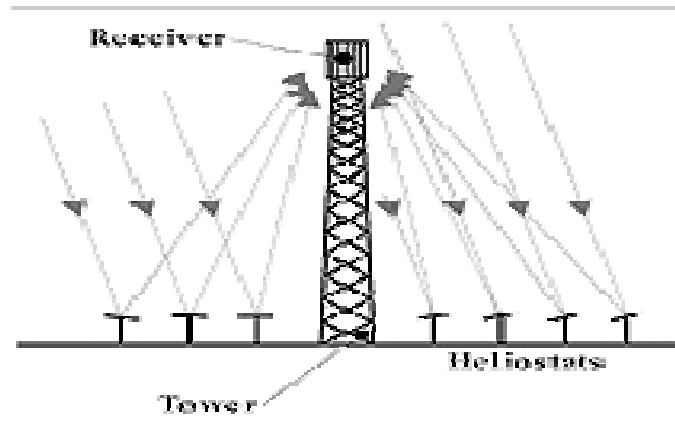


Figure (2.11) Power Tower System.

The below figure (2.12) shows Heliostats.



Figure (2.12) Heliostats .

A power tower has a field of large mirrors that follow the sun's path across the sky. The mirrors concentrate sunlight onto a receiver on top of a high tower. A computer keeps the mirrors aligned so the reflected rays of the sun are always aimed at the receiver, where temperatures well above 1000°C can be reached. High-pressure steam is generated to produce electricity ^[12].

The below figure (2.13) shows The power tower system with heliostats .



Figure (2.13) Power Tower System With Heliostats.

2.7.1.4 Stationary Concentrating Solar Collectors:

Stationary concentrating collectors use compound parabolic reflectors and flat reflectors for directing solar energy to an accompanying absorber or aperture through a wide acceptance angle. The wide acceptance angle for these reflectors eliminates the need for a sun tracker. This class of collector includes parabolic trough flat plate collectors, flat plate collectors with parabolic boosting reflectors, and solar cooker. Development of the first two collectors has been done in Sweden. Solar cookers are used throughout the world, especially in the developing countries ^[12].

CHAPTER THREE

CHAPTER THREE

3. RADIATION

3.1 Background:

Solar radiation emission from the sun into every corner of space appears in the form of electromagnetic waves that carry energy at the speed of light. The solar radiation is absorbed, reflected, or diffused by solid particles in any location of space and especially by the earth, which depends on its arrival for many activities such as weather, climate, agriculture, and socio-economic movement. Depending on the geometry of the earth, its distance from the sun, geographical location of any point on the earth, astronomical coordinates, and the composition of the atmosphere, the incoming irradiation at any given point takes different shapes. A significant fraction of the solar radiation is absorbed and reflected back into space through atmospheric events and consequently the solar energy balance of the earth remains the same ^[14].

3.2 Solar Radiation:

Solar radiation from the sun after traveling in space enters the atmosphere at the space-atmosphere interface, where the ionization layer of the atmosphere ends. Afterwards, a certain amount of solar radiation or photons are absorbed by the atmosphere, clouds, and particles in the atmosphere, a certain amount is reflected back into the space, and a certain amount is absorbed by the earth's surface. The earth's surface also reflects a certain amount of energy by radiation at different wavelengths due to the earth's surface temperature. About 50% of the total solar radiation remains in the atmosphere and earth's surface. The earth's rotation around its axis produces hourly variations in power intensities at a given location on the ground during the daytime and results in complete shading during the nighttime ^[14].

The presence of the atmosphere and associated climate effects both attenuate and change the nature of the solar energy resource. The combination of reflection, absorption (filtering), refraction, and scattering result in highly dynamic radiation levels at any given location on the earth. As a result of the cloud cover and scattering sunlight, the radiation received at any point is both direct (or beam) and diffuse (or scattered).

After the solar radiation enters the earth's atmosphere, it is partially scattered and partially absorbed. The scattered radiation is called diffuse radiation. Again, a

portion of this diffuse radiation goes back to space and a portion reaches the ground. Solar radiation reaches the earth's surface in three different ways as direct, diffuse, and reflected irradiances as in Figure (3.1).

The quantity of solar radiation reaching any particular part of the earth's surface is determined by the position of the point, time of year, atmospheric diffusion, cloud cover, shape of the surface, and reflectivity of the surface.

However, in hilly and mountainous terrains, the distribution of slopes has major effects on surface climate and radiation amounts. Surface radiation may change widely according to the frequency and optical thickness of clouds, and modeling these cloud properties successfully is important for treatment of the surface energy balance ^[14].

Direct solar radiation is that which travels in a straight line from the sun to the earth's surface. Clear-sky day values are measured at many localities in the world. To model this would require knowledge of intensities and direction at different times of the day. Direct radiation as the name implies is the amount of solar radiation received at any place on the earth directly from the sun without any disturbances. In practical terms, this is the radiation which creates sharp shadows of the subjects. There is no interference by dust, gas, and cloud or any other intermediate material on the direct solar radiation. Direct radiation is practically adsorbed by some inter-mediator and then this inter-mediator itself radiates EM waves similar to the main source which is the sun. Direct solar radiation can be further reflected and dispersed across the surface of the earth or back into the atmosphere. On the other hand, the radiation arriving on the ground directly in line from the sun is called direct or beam radiation in Figure (3.1a). Beam radiation is the solar radiation received from the sun without scatter by the atmosphere. It is referred to as direct solar radiation. This is actually the photon stream in space and has a speed of 3,000,000 km/s ^[14].

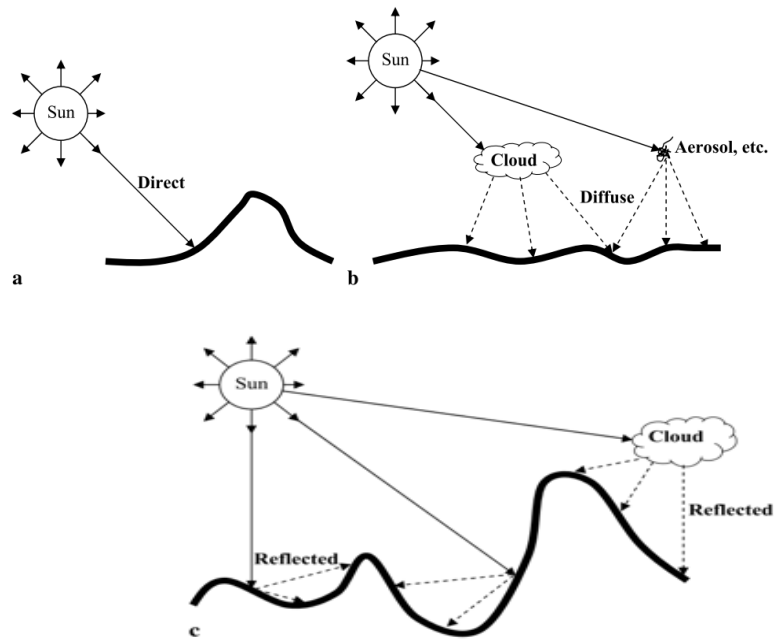


Figure (3.1a-c) Solar Radiation Paths. a. Direct b. Diffuse c. Reflected

Passing through the atmosphere, the solar beam undergoes wavelength- and direction-dependent adsorption and scattering by atmospheric gases, aerosols, and cloud droplets. The scattered radiation reaching the earth's surface is referred to as diffuse radiation in Figure (3.1b). Diffuse radiation is first intercepted by the constituents of the air such as water vapor, CO₂, dust, aerosols, clouds, etc., and then released as scattered radiation in many directions. This is the main reason why diffuse radiation scattering in all directions and being close to the earth's surface as a source does not give rise to sharp shadows. When the solar radiation in the form of an electromagnetic wave hits a particle, a part of the incident energy is scattered in all directions and it is called diffuse radiation. All small or large particles in nature scatter radiation. Diffuse radiation is scattered out of the solar beam by gases (Rayleigh scattering) and by aerosols (which include dust particles, as well as sulfate particles, soot, sea salt particles, pollen, etc.). Reflected radiation is mainly reflected from the terrain and is therefore more important in mountainous areas. Direct shortwave radiation is the most important component of global radiation because it contributes the most to the energy balance and also the other components depend on it, either directly or indirectly. Diffuse radiation occurs when small particles and gas molecules diffuse part of the incoming solar radiation in random directions without any alteration in the wavelength of the electromagnetic energy^[15].

Solar energy modeling requires knowledge of surface reflectance and shape, and a means of modeling any dispersal. Albedo is a measure of how much radiation is reflected by a surface. When the albedo is 1.0 all radiation is reflected; none is absorbed. When the albedo is 0.0 no radiation is reflected; it is all absorbed. A significant proportion of direct solar radiation striking a surface is reflected, particularly from snow and clouds. What proportion of the reflected radiation strikes another surface is not known ^[16].

Diffuse radiation occurs when small particles and gas molecules diffuse part of the incoming solar radiation in random directions without any alteration in the wavelength of the electromagnetic energy. Diffuse cloud radiation would require modeling of clouds, which was considered impossible to do and would have been variable from day to day. It appears to only contribute a minor part to radiation energies from above the mid-visible through to the infrared spectrum, but can contribute up to 40% of the radiation energy from the mid-visible through to the mid-ultraviolet spectrum ^[14].

Total (global) solar radiation is the sum of the beam and the diffuse solar radiation on a surface. The most common measurements of solar radiation are total radiation on a horizontal surface, hereafter referred to as global radiation on the surface. The total solar radiation is sometimes used to indicate quantities integrated over all wavelengths of the solar spectrum. The sun's total energy is composed of 7% ultraviolet (UV) radiation, 47% visible radiation, and 46% infrared (heat) radiation. UV radiation causes many materials to degrade and it is significantly filtered out by the ozone layer in the upper atmosphere ^[15].

The total global radiation at the earth's surface consists of both short- and long wave radiation. Short-wave radiation may be absorbed by terrestrial bodies and cloud cover and re-emitted as long-wave radiation. The short-wave radiation reaching the surface of the earth may be direct, diffuse, or reflected.

Global radiation at a location is roughly proportional to direct solar radiation, and varies with the geometry of the receiving surface. The other components, such as diffuse radiation, vary only slightly from slope to slope within a small area and the variations can be linked to slope gradient ^[14].

The flux of clear-sky diffuse radiation varies with slope orientation in much the same way as the flux of direct solar radiation, hence preserving the spatial variability in total radiation ^[14].

3.3. Parallel Solar Radiation:

Rays emanating from the sun's surface are homogeneous and identical in all directions. Earth receives radiation from the sun. It is widening the farther from the sun in space. Cosmic rays can be considered the hypotenuse to the earth's surface as parallel rays to the small diameter of the Earth to the sun diameter. On the other hand, the breakthrough solar rays that form the radioactive package falling on the surface of the earth is very small.

3.4 Solar Constant:

The sun's radiation is subject to many absorbing, diffusing, and reflecting effects within the earth's atmosphere which is about 10 km average thick and, therefore, it is necessary to know the power density, watts per meter per minute on the earth's outer atmosphere and at right angles to the incident radiation. The density defined in this manner is referred to as the solar constant. The solar constant and the associated spectrum immediately outside the earth's atmosphere are determined solely by the nature of the radiating sun and the distance between the earth and the sun.

Earth receives virtually all of its energy from space in the form of solar radiation. Its total heat content does not change significantly with time, indicating a close overall balance between absorbed solar radiation and the diffuse stream of low-temperature, thermal radiation emitted by the planet. The radiance at the mean solar distance – the solar constant – is about 1360 W/m^2 . At the mean earth–sun distance the sun subtends an angle of 32° . The radiation emitted by the sun and its spatial relationship to the earth result in a nearly fixed intensity of solar radiation outside the earth's atmosphere. The solar constant, I_{sc} (W/m^2), is the energy from the sun per unit time per unit area of surface perpendicular to the direction of the propagation of the radiation. The measurements made with a variety of instruments in separate experimental programs resulted as $I_{sc}=1353 \text{ W/m}^2$ with an estimated error of $\pm 1.5\%$. The World Radiation Center has adopted a value of 1367 W/m^2 with an uncertainty of 1%. The most updated solar constant is $I_{sc}=1367 \text{ W/m}^2$, which is equivalent to $I_{sc}=1.960 \text{ Cal/cm}^2 \text{ min}$ or $432 \text{ Btu/ft}^2\text{h}$ or $4.921 \text{ MJ/m}^2\text{h}$ [17]. The best value of the solar constant available at present is $I_{sc}=1360 \text{ W/m}^2$ [14].

3.5 Solar Radiation Calculation:

Solar irradiance, I (W/m^2), is the rate at which radiant energy is incident on a unit surface. The incident energy per unit surface is found by integration of irradiance over a specified time, usually an hour or a day. Insolation is a term specifically for solar energy irradiation on surfaces of any orientation.

There are two dimensions to the energy flux due to the energy of photons and the energy itself. Specialists in “solar energy” think in terms of an integrated expression over a certain time interval and have the dimension of energy, J , which is “insolation” as the integrated “irradiance”.

In general, modeling the solar radiation arriving at the top of the atmosphere can simply be considered as the product of the solar constant I_{sc} and the astronomical factor $f(R)$ of annual average 1.0, proportional to R^{-2} (inverse distance square), where R is the distance of the earth from the sun. Under cloudy or partly cloudy conditions, diffuse radiation is anisotropic which may be explicitly modeled, but in practice this is computationally expensive to achieve as the diffuse radiation from different portions of the sky must be calculated. In order to calculate actual solar flux, field data from pyranometers (which measure actual incoming solar flux at a station), atmospheric optical data, or atmospheric profiling (sounding) must be used.

If I is the intensity of radiation arriving at the ground surface from a given direction, then the amount incident per unit surface area along the zenith direction is
The direct solar rays = $I_{dn} * \cos(I)$ (3.1)

Where:

I = Is the Incidence angle between the normal to the surface and the direction of the beam see Figure (3.2).

The solar radiation varies according to the orbital variations. If I_t is the total solar radiation output from the sun at all frequencies then at a distance R from the sun's center, the flux of the radiation will be the same assuming that the radiation is equal in all directions.

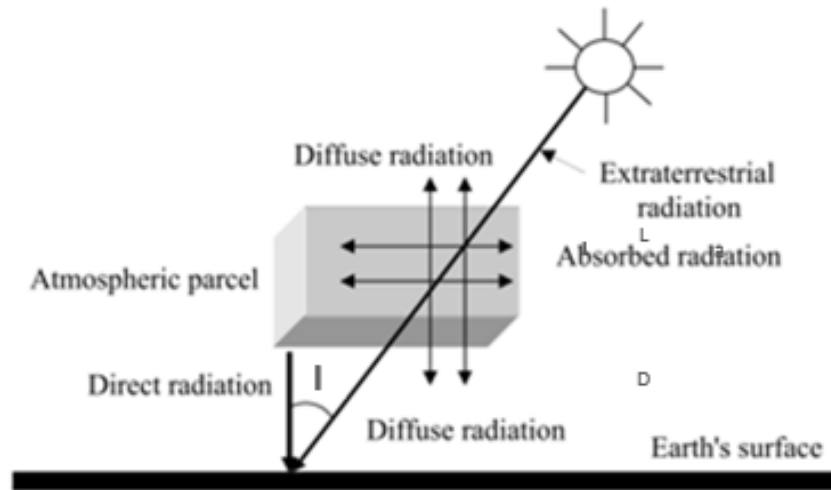


Figure (3.2) Surface Solar Radiation

The driving force for the atmosphere is the absorption of solar energy at the earth's surface. Over time scales which are long compared to those controlling the redistribution of energy, the earth-atmosphere system is in thermal equilibrium. The absorption of solar radiation, at visible wavelengths as short-wave (SW) radiation, must be balanced by the emission to space of infrared or long-wave (LW) radiation by the planet's surface and atmosphere. A simple balance of SW and LW radiations leads to an equivalent blackbody temperature for the earth as $T=255$ K. This is some 30 K colder than the global mean surface temperature, $T_s \approx 288$ K. The difference between these two temperatures follows from the greenhouse effect which results from the different ways the atmosphere processes SW and LW radiations. Although transparent to SW radiation (wavelength $\approx 1 \mu m$), the same atmosphere is almost opaque to LW radiation (wavelength $\approx 10 \mu m$) re-emitted by the planet's surface. By trapping radiant energy that must eventually be rejected into space, the atmosphere's capacity elevates the surface temperature beyond what it would be in the absence of an atmosphere ^[14].

The change in extraterrestrial solar radiation can be calculated by taking into account the astronomical facts according to the following formula:

$$I = I_{sc} (1 + 0.33 \cdot \cos(\frac{360 \cdot n}{365})) \dots\dots\dots (3.2)$$

Where:

n = is the number of the day corresponding to a given date. It is defined as the number of days elapsed in a given year up to a particular date starting from 1 on 1 January to 365 on 31 December.

I_{sc} = Solar Constant.

3.6 Solar Radiation Measuring Equipment:

A number of radiation parameters are needed for the design, sizing, performance evaluation, and research of solar energy applications. These include total solar radiation, beam radiation, diffuse radiation, and sunshine duration. Various types of equipment measure the instantaneous and long-term integrated values of beam, diffuse and total radiation incident on a surface. This equipment usually employs the thermoelectric and photovoltaic effects to measure the radiation.

There are basically two types of solar radiation measuring instruments: the pyranometer Figure (3.3) and the pyrliometer Figure (3.4). The former is used to measure total (beam and diffuse) radiation within its hemispherical field of view, whereas the latter is an instrument used for measuring the beam radiation at normal incidence. The pyranometer can also measure the diffuse solar radiation if the sensing element is shaded from the beam radiation. For this purpose a shadow band is mounted with its axis tilted at an angle equal to the latitude of the location plus the declination for the day of measurement. Since the shadow band hides a considerable portion of the sky, the measurements require corrections for that part of diffuse radiation obstructed by the band. Pyrliometers are used to measure direct solar irradiance, required primarily to predict the performance of concentrating solar collectors. Diffuse radiation is blocked by mounting the sensor element at the bottom of a tube pointing directly at the sun. Therefore, a two-axis sun-tracking system is required to measure the beam radiation.

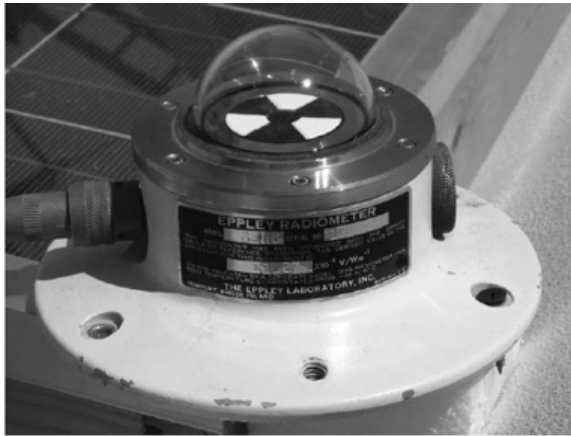


Figure (3.3) Photograph of Pyranometer

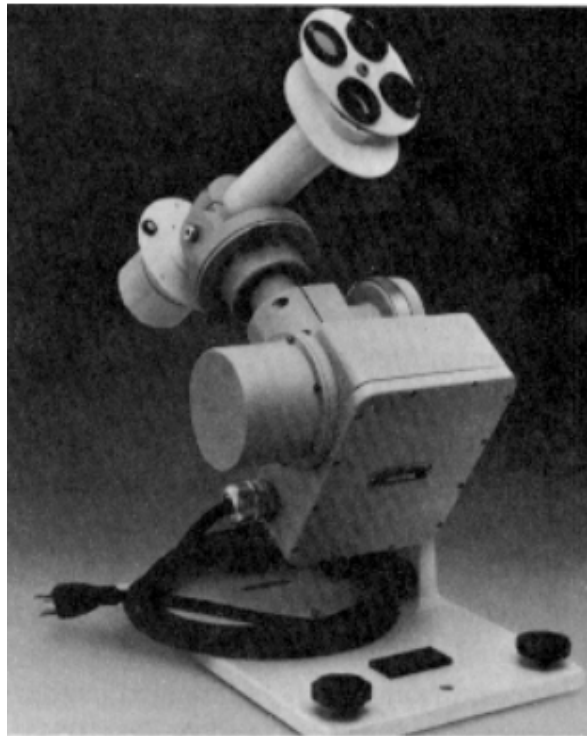


Figure (3.4) Photograph of Pyrheliometers

Finally, sunshine duration is required to estimate the total solar irradiation.

3.7 Solar Parameters:

Solar radiation and energy calculations require some geometric and time quantities concerning the sun position relative to the earth and any point on the earth. It is also necessary to know the relation between the local standard time and the solar time.

3.7.1 Solar Time:

Solar time is based not only on the rotation of the earth about its axis but also on the earth's revolution around the sun during which the earth does not sweep equal areas on the ecliptic plane Figure (3.5).

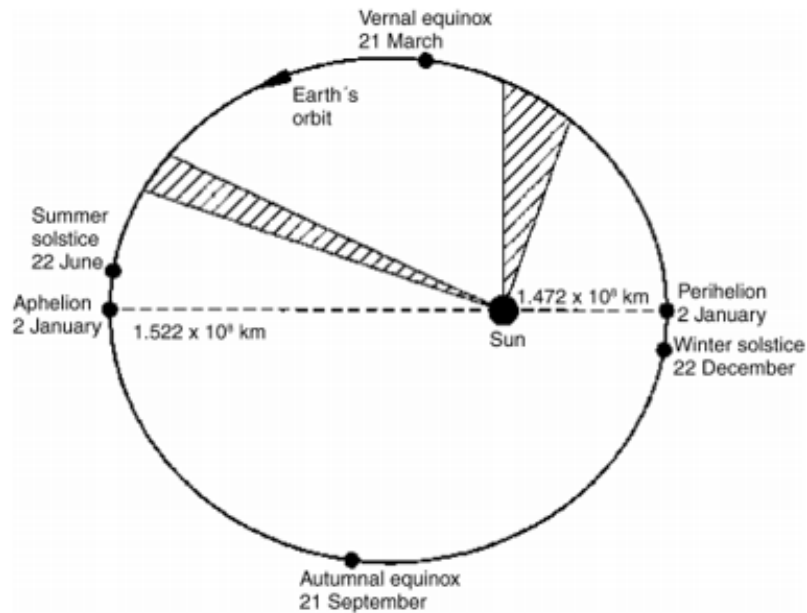


Figure (3.5) Earth's Orbit around The Sun

3.7.1.1 Equation of Time (E):

These combined movements, cause small discrepancies in the sun's appearance exactly over the local meridian daily. This discrepancy is the align of time, E, which is expressed by Spencer as:

$$E = 229.2 * (0.000075 + 0.001868 * \cos(B) - 0.032077 * \sin(B) - 0.014615 * \cos(2*B) - 0.04089 * \sin(2*B)) \dots\dots\dots (3.3)$$

Where day angle B in radians is given as

$$B = ((n-1) * (360/365)) \dots\dots\dots (3.4)$$

3.7.1.2 Apparent Solar Time (S_{ot}):

Most meteorological measurements are recorded in terms of local standard time. In many solar energy calculations, it is necessary to obtain irradiation, wind, and temperature data for the same instant. It is, therefore, necessary to compute local apparent time, which is also called the true solar time. Solar time is the time to be used in all solar geometry calculations. It is necessary to apply the corrections due to the difference between the local longitude, L_{loc}, and the longitude of the standard

time meridian, L_{st} . The apparent time S_{ot} , can be calculated by considering the standard time, S_t , according to Iqbal as:

$$S_{ot} = S_t \pm 4(L_{st} - L_{loc}) + E \quad \dots\dots\dots (3.5)$$

In this expression + (–) sign is taken in degrees toward the west (east) of the 0° meridian (longitude), which passes through Greenwich in the UK. All terms in the above equation are to be expressed in hours.

3.7.2 Useful Angles:

The basic angles that are necessary in the definition of the geographic locations are latitude, L , and longitude, ϕ .

3.7.2.1 The Latitude (L):

The latitude is the angular distance measured along a meridian from the equator (north or south) to a point on the earth's surface. Any location towards the north (south) has positive (negative) latitude with maximum degrees as +90 (–90) at the north (south) pole Figure (3.6).

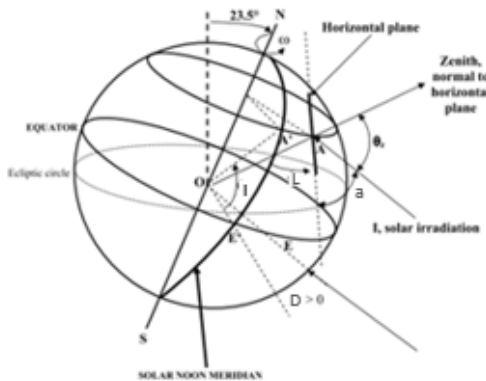


Figure (3.6) Useful Angles

The position of the sun can be calculated for any location and any time as shown in Figure (3.7). The position of the sun is given by two angles, which are altitude, a , and azimuth angle, A . The altitude (or elevation) is the angle of the sun above the horizon and azimuth (or bearing) is the angle from north to the projection on the earth of the line to the sun. The solar position is symmetrical about solar noon (which is different than 12 noon local time). Irradiation fluctuates according to the weather and the sun's location in the sky. This location constantly changes throughout the day due to changes in both the sun's altitude (or elevation) angle and its azimuth angle.

Figure (3.7) shows the two angles used to specify the sun's location in the sky^[14].

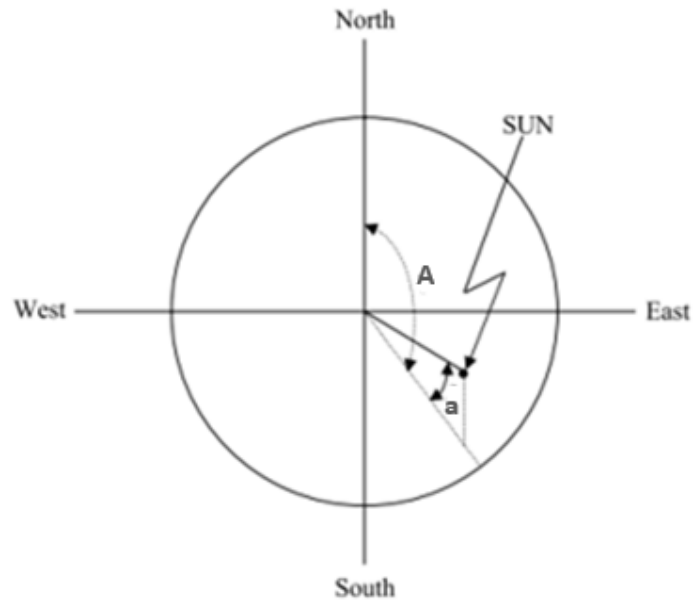


Figure (3.7) Position of the Sun by Altitude And Azimuth

3.7.2.2 The Declination Angle (D):

The declination angle is the angle between the earth–sun line and the equatorial plane, which changes with the date and it is independent of the location figure (3.6). The declination is maximum $23^{\circ}45'$ on the summer/winter solstice and 0° on the equinoxes figure (3.8).

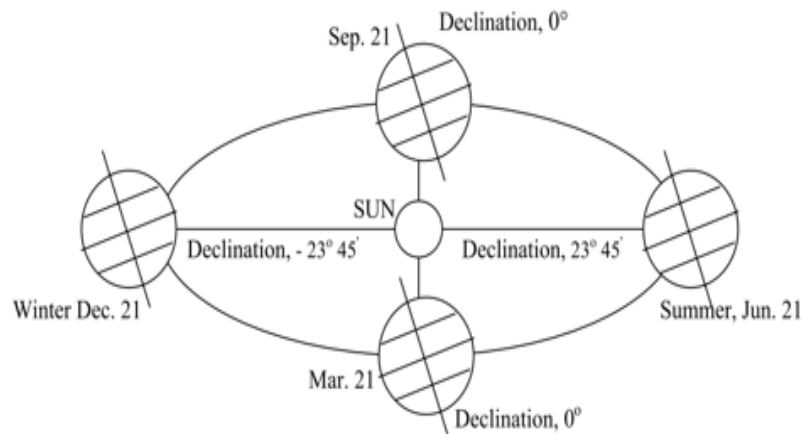


Figure (3.8) The declination angles

$$D=23.45*\sin ((360/365)*(284+n)) \dots\dots\dots (3.6)$$

3.7.2.3 The Hour Angle (w):

The hour angle is the angular distance that the earth rotates in a day, which is equal to 15° multiplied by the number of hours ($15 \times 24 = 360^\circ$) from local solar noon figure (3.6). This is based on the nominal time, 24 h, required for the earth to rotate once, 360° . Values east (west) of due south (north), morning (evening) are positive (negative). Hence, the w can be defined by

$$w = (Stt - 12) \times 15 \dots \dots \dots (3.7)$$

Where

Stt = is the current hour of the day.

3.7.2.4 The Solar Altitude Angle (a):

The solar altitude is the vertical angle between the horizontal and the line connecting to the sun. At sunset (sunrise) altitude is 0° and 90° when the sun is at the zenith. The altitude relates to the latitude of the site, the declination angle, and the hour angle.

$$\sin(a) = \sin(L) \times \sin(D) + \cos(L) \times \cos(D) \times \cos(W) \dots \dots \dots (3.8)$$

3.7.2.5 The Slop Angle (B₁):

The angle between the plane of the surface in question and the horizontal $0 \leq B_1 \leq 180^\circ$.

3.7.2.6 The Solar Azimuth Angle (A):

The solar azimuth angle is the angle of the sun's rays measured in the horizontal plane from due south (true south) for the Northern Hemisphere or due north for the Southern Hemisphere, westward is designated as positive. The mathematical expression for the solar azimuth angle is

$$\sin(A) = ((\cos(D) \times \sin(W)) / \sin(a)) \dots \dots \dots (3.9)$$

3.7.2.7 The Surface Azimuth Angle (A_s):

The deviation of the projection on a horizontal plane of the normal to the surface from the local meridian, with zero due south, east negative, and west positive $-180^\circ \leq A_s \leq 180^\circ$.

3.7.2.8 The Incidence Angle (I):

The Incidence angle between the beam and vertical angle on the surface and is calculated from the following relationship

$$\begin{aligned} \cos(I) = & \sin(D) * \sin(L) * \cos(B1) - \sin(D) * \cos(L) * \sin(B1) * \cos(A) + \\ & \cos(L) * \cos(D) * \cos(w) * \cos(B1) + \sin(L) * \cos(D) * \cos(w) * \\ & \sin(B1) * \cos(A) + \cos(D) * \sin(w) * \sin(B1) * \sin(A) \dots \dots \dots (3.10) \end{aligned}$$

3.7.2.9 The Zenith Angle (θ_z):

The zenith angle is the angle between the vertical and the line connecting to the sun (the angle of incidence of beam radiation on a horizontal surface). Likewise, the angle between the horizontal and the line to the sun is the solar altitude angle, (the complement angle of the zenith angle), hence $a + \theta_z = 90^\circ$.

$$\cos \theta_z = \cos L \cos D \cos W + \sin L \sin D \dots \dots \dots (3.11)$$

Note that at solar noon the hour angle equals zero and since the hour angle changes at 15° per hour it is a simple matter to calculate the hour angle at any time of day. The hour angles at sunrise and sunset (w_s) are very useful quantities to know. Numerically these two values have the same value however the sunrise angle is negative and the sunset angle is positive. Both can be calculated from:

$$\cos w_s = -\tan L \tan D \dots \dots \dots (3.12)$$

This equation is derived by substituting $\theta_z = 0$ into equation (3.9). w_s can be used to find the number of daylight hours (N) for a particular day using the next equation, where w_s is in radians:

$$N = \frac{2w_s}{15} \times \frac{180}{\pi} \dots \dots \dots (3.13)$$

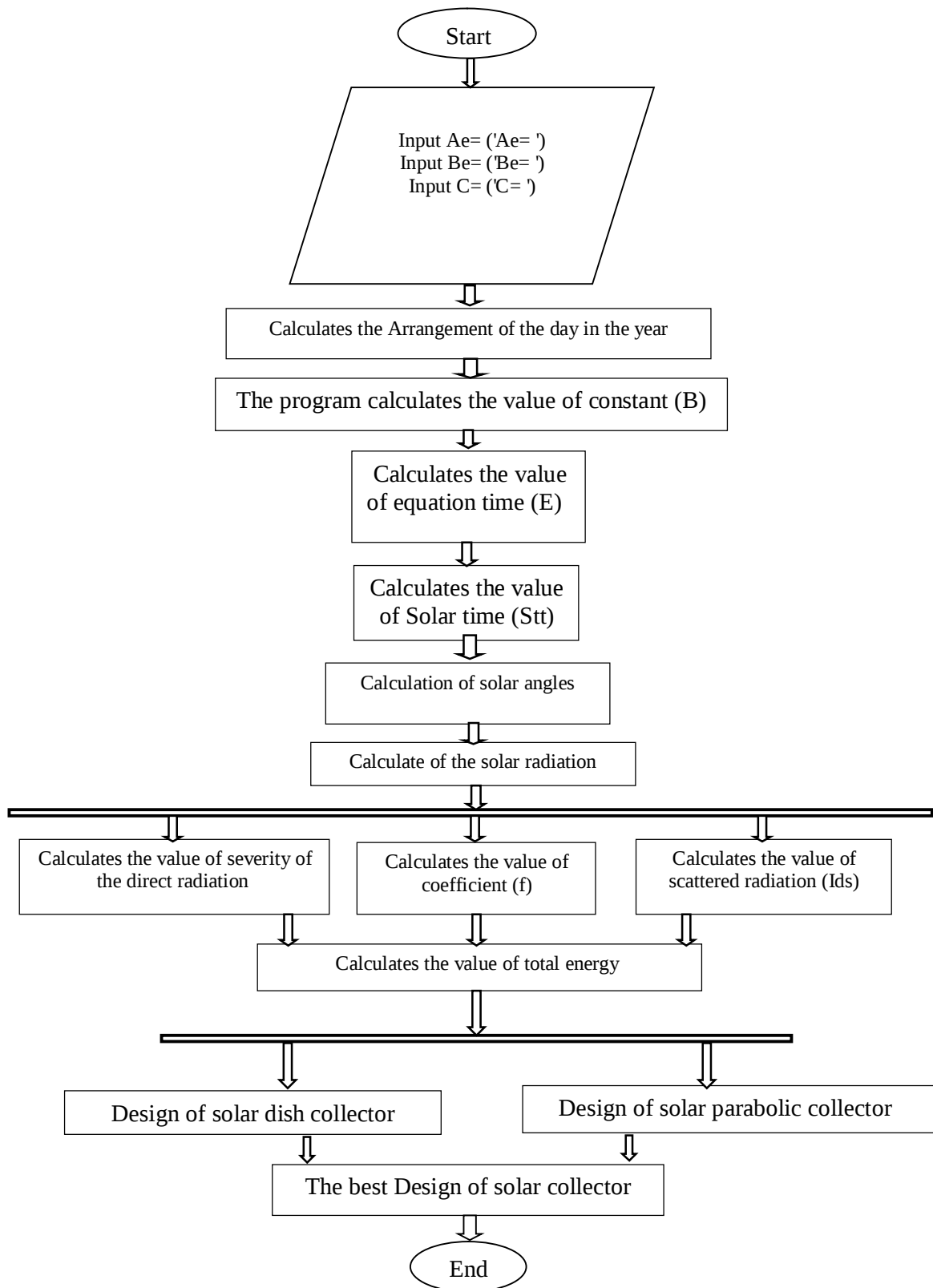
CHAPTER FOUR

CHAPTER FOUR

4. RESEARCH METHODOLOGY

4.1 Background

This chapter explained the way the program design worked using MATLAB language to calculate the dimensions of solar collectors. Calculated the power required for the production of steam and solar angles through the data, including the geographical location of the study area and specifications of the steam input required. The following is the program outline.



The overall shape of the work program

Table (4.1) The Characteristics of Solar Radiation That the Program Required To be Entered At the Start of Implementation.

Month	January	February	March	April	May	Jun	July	August
Solar noon	Late			Early		Late		
Ae W/m ²	1229.12	1213.36	1185	1134.57	1103.06	1087.3	1084.15	1106.21
Be(1/m)	0.142	0.144	0.156	0.180	0.196	0.205	0.201	0.177
C	0.058	0.060	0.071	0.097	0.121	0.134	0.136	0.122

September	October	November	December
Early			
1150.33	1191.3	1219.67	1232.27
0.160	0.149	0.149	0.142
0.092	0.073	0.063	0.057

Table (4-1) Solar Radiation Properties

Where:

Ae≡Severity of the solar radiation of apparent cosmic.

B≡Extinction coefficient of the air.

C≡ Is the ratio between the scattered to of direct radiation incident on a horizontal surface.

4.2 Calculation of the Day in the Year:

Table (4.2) Recommended Average Days for Months and Values of n by Months

Month	Day of month	Date	n, Day of year
January	X	1	1
February	31+X	1	32
March	59+X	1	60
April	90+X	1	91
May	120+X	1	121
June	151+X	1	152
July	181+X	1	182
August	212+X	1	213
September	243+X	1	244
October	273+X	1	274
November	304+X	1	305
December	334+X	1	335

Where:

n = Day of year

4.3 Calculations of Solar Angles:

4.3.1 Calculation Solar Time (S_{ot}):

$$S_{ot} = S_t \pm 4(L_{st} - L_{loc}) + E \quad \dots\dots\dots (4.1)$$

Where:

L_{st} = the standard meridian for the local time zone, degrees.

L_{loc} = the longitude of the location west or east, degrees.

E = the equation of time, minutes.

Calculated from the relationship (E):

$$E = 229.2 * (0.000075 + 0.001868 * \cos(B) - 0.032077 * \sin(B) - 0.014615 * \cos(2*B) - 0.04089 * \sin(2*B)) \quad \dots\dots\dots (4.2)$$

Calculated from the relationship (B):

$$B = ((n-1) * (360/365)) \quad \dots\dots\dots (4.3)$$

Where:

n = Day of year

Then, the program calculates the equation of time (E) and solar time (S_{ot}).

4.3.2 Calculation the Hour Angle (w):

$$w = (Stt - 12) * 15 \dots\dots\dots (4.5)$$

Where

Stt= the current hour of the day.

4.3.3 Calculation of the Declination Angle (D):

Calculated from the relationship:

$$D = 23.45 * \sin((360/365) * (284 + n)) \dots\dots\dots (4.6)$$

Then, the program calculates the value of angle of declination in each day of the year.

4.3.4 Calculation of the Altitude Angle (a):

Calculated from the relationship:

$$\sin(a) = \sin(L) * \sin(D) + \cos(L) * \cos(D) * \cos(W) \dots\dots\dots (4.7)$$

Where:

L= latitude angle

Then the program calculates the values of angle of altitude (a) in each day of the year.

4.3.5 Calculation of the Azimuth Angle (A):

Calculated from the relationship:

$$\sin(A) = ((\cos(D) * \sin(W)) / \sin(a)) \dots\dots\dots (4.8)$$

Then the program calculates the values of angle of Azimuth (A) in each day of the year.

4.3.6 Calculation of the Incidence Angle (I):

$$\begin{aligned} \cos(I) = & \sin(D) * \sin(L) * \cos(B1) - \sin(D) * \cos(L) * \sin(B1) * \cos(A) + \\ & \cos(L) * \cos(D) * \cos(w) * \cos(B1) + \sin(L) * \cos(D) * \cos(w) * \sin(B1) * \cos(A) + \\ & \cos(D) * \sin(w) * \sin(B1) * \sin(A) \dots\dots\dots (4.9) \end{aligned}$$

Where:

B1= slop angle

Then the program calculates the values of angle of Incidence (I) in each day of the year.

4.4 calculations of solar radiation:

The calculation of the severity of the direct radiation (Idn) from the following equation:

$$Idn = Ae * \exp - (Be / \sin(a)) \dots\dots\dots (4.10)$$

Where:

A_e = severity of the solar radiation of apparent cosmic

B_e = Atmospheric extinction coefficient

And then calculate the (F) is the coefficient of the angle between the surface and space, and it calculate of the equation:

$$F = ((1 + \cos B_1)/2) \dots\dots\dots (4.11)$$

$$I_{ds} = C * I_{dn} * F \dots\dots\dots (4.12)$$

Where:

I_{ds} = the scattered solar radiation (w/m^2)

C = the ratio between the scattered to direct radiation incident on horizontal surface.

And gives the flow of the total solar energy (I_t (w/m^2)) on surface is in the scope of the globe at any tendency and the direction of this surface if the values of Incidence angle (I) calculated from the equation :

$$I_t = I_{dn} * \cos(I) + I_{ds} \dots\dots\dots (4.13)$$

Where:

The direct solar rays = $I_{dn} * \cos(I)$

And then calculate the solar energy (E_t (w/m^2)) from the equation:

$$E_t = E_e * I_t \dots\dots\dots (4.14)$$

Where:

E_e = the total atmospheric Emissivity which as sums values between 0 and 1

4.5 Calculations of Solar Collectors:

4.5.1 Calculations of Total Solar Energy Required From the Solar Collectors:

The calculation of the total energy of the required to generate any quantity from steam at specific pressure and temperature is explored below.

The entering of value of (m_s) to the program:

$m_s = 2$ ton

The entering of value of temperature of water (T_1 (K)) to the program:

$T_1 = 300$ K

The entering of value boiling temperature of water (T_2 (K)) to the program:

$T_2 = 373$ K

The entering of value specific heat of water (C_{pw} (KJ/Kg.K)) to the program

$$C_{pw} = 4.18 \text{ KJ/Kg.K}$$

- And then calculation the thermal energy needed to raise the temperature of water to a temperature of boiling (Q_1) from the relationship:

$$Q_1 = C_{pw} * m_s * (T_2 - T_1) \dots\dots\dots (4.15)$$

The interring of value of latent heat for vapor at boiling point (hfg (KJ/Kg)) to the program, taken from the steam table.

$$h_{fg} = 2256.7 \text{ kJ/Kg}$$

- And then calculation the necessary energy to change water to steam at boiling point (Q_2).

$$Q_2 = m_s * h_{fg} \dots\dots\dots (4.16)$$

The interring of value of enthalpy of the steam at the degree of superheating (h_{sup} (KJ/Kg)) to the program, taken from the steam table of the superheated.

$$h_{sup} = 2829 \text{ kJ/Kg}$$

The interring of value of enthalpy of the steam at the temperature of boiling water (hg at 100°C (KJ/Kg)) to the program, taken from the steam table of the saturated steam at a temperature of 100°C.

$$h_{g(at 100^\circ C)} = 2675.8 \text{ kJ/Kg}$$

- And then calculation the energy required for superheating steam (Q_3):

$$Q_3 = m_s * (h_{sup} - h_{g(at 100^\circ C)}) \dots\dots\dots (4.17)$$

- And then calculation the energy of lost from the solar collectors are 25% of total energy (Q_4)

$$Q_{total} = Q_1 + Q_2 + Q_3 \dots\dots\dots (4.18)$$

$$Q_4 = 0.25 * Q_{total} \dots\dots\dots (4.19)$$

- And then calculation total energy required (Ein)

$$E_{in} = Q_{total} + Q_4 \dots\dots\dots (4.20)$$

4.5.2 Calculation of the dimensions of the solar collectors:

4.5.2.1 Calculation of the dimensions of the dish solar collector:

- Diameter of the solar collector (d):

The diameter of the solar collector is calculated from the relationship between the energy that required to produce the steam and average incident solar radiation per square meter:

$$E_{in} = 1/3 * \pi * d^2 * f \dots\dots\dots (4.21)$$

Where:

f= average incident solar radiation in year.

$$f = \text{sum} (I_{dn})/365 \dots\dots\dots (4.22)$$

Taken one third of the area of the collector in order to avoid a shadow over internal aspects of the solar collector.

And then calculation the output energy from the relationship:

$$E_{out}=0.5*f*\pi*d^2 \dots\dots\dots (4.23)$$

And then calculation the efficiency of dish collector (eff) from the relationship:

$$\text{eff} = E_{in}/E_{out} \dots\dots\dots (4.24)$$

Rise of the solar collector (ri):

The rise of the solar collector is calculated from the relationship:

$$r_i = (d/2)^2 / (4 * F_d) \dots\dots\dots (4.25)$$

Where:

F_d = focus of the dish collector

The interference of value of focus of the dish collector (F_d) to the program:

F_d= 0.75m

4.5.2.2 Calculation of the Dimensions of the Parabolic Solar Collector:

- length of the solar collector (l₂):

The length of the solar collector is calculated from the relationship between the energy that required to produce the steam and average incident solar radiation per square meter and diameter of the solar collector:

$$E_{in} = 1/3 * \pi * d_2^2 * f * l_2 \dots\dots\dots (4.26)$$

Where:

f= average incident solar radiation in year.

$$f = \text{sum} (I_{dn})/365 \dots\dots\dots (4.27)$$

Taken one third of the area of the collector in order to avoid a shadow over internal aspects of the solar collector.

d = assume Appropriate diameter.

And then calculation the output energy from the relationship:

$$E_{out}=0.5*f*\pi*d_2^2 * l_2\dots\dots\dots (4.28)$$

And then calculation the efficiency of parabolic collector (eff) from the relationship:

$$\text{eff} = E_{\text{in}}/E_{\text{out}} \dots\dots\dots (4.29)$$

- Rise of the solar collector(r_i):

The rise of the solar collector is calculated from the relationship:

$$r_i = (d/2)^2 / (4 * F_d) \dots\dots\dots (4.30)$$

Where:

F_d = focus of the parabolic collector

The interference of value of focus of the parabolic collector (F_d) to the program:

$$F_d = 0.75\text{m}$$

CHAPTER FIVE

CHAPTER FIVE

5. RESULT AND DISCUSSIONS

5-1 Analysis of Results:

When you start the program implementation calculates the in the year
Then work on the implementation of the scheme shown in Figure (5.1) the
relationship between the days in the months and days in the year.

We note in Figure (5.1) that the value of today is rising every day depending
on the month in the year.

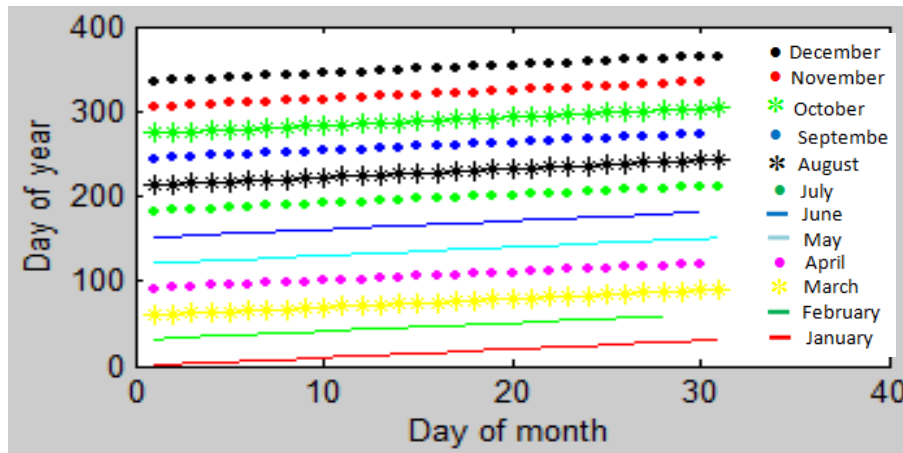


Figure (5.1) Relationship a Day of the Month Correspond To a Day of the Year
Then, the program calculates the equation of time (E) and solar time (Sot).
Then the implementation of the diagram in Figure (5.2) in which the relationship
between the Year days and equation of time is illustrated.

We note in the Figure (5.2) the minimum value of the equation of time of day
45 of the year is the value of -14.2676 and the highest value of the equation of time
of day 306 of the year is the value of 16.3887.

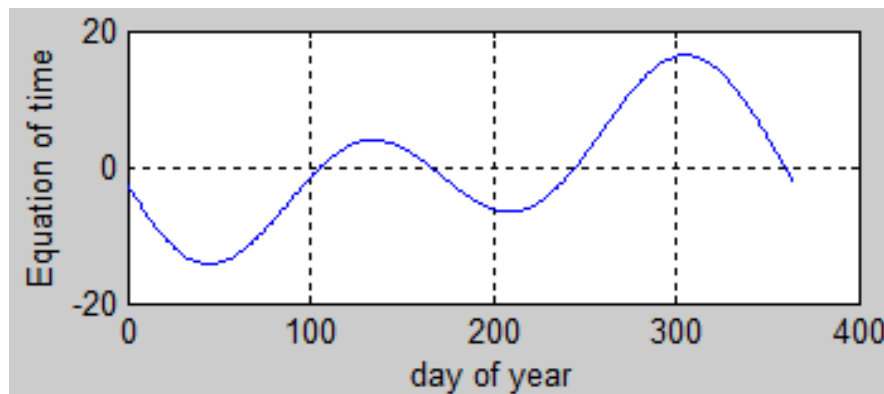


Figure (5.2) Relationship a Day of the Year and Equation of Time

Then, the program calculates the value of angle of declination in each day of the year.

Then the implementation of the diagram in Figure (5.3) in which the relationship between the Year days and declination angle is illustrated.

We note in the Figure (5.3) the value of the angle of declination increases from the value of -23.0116° at the beginning of the year until it reaches the highest value at 23.4498° at the day 172 of the year and then begin to decrease until it reaches a value -23.0859° at the end of the year.

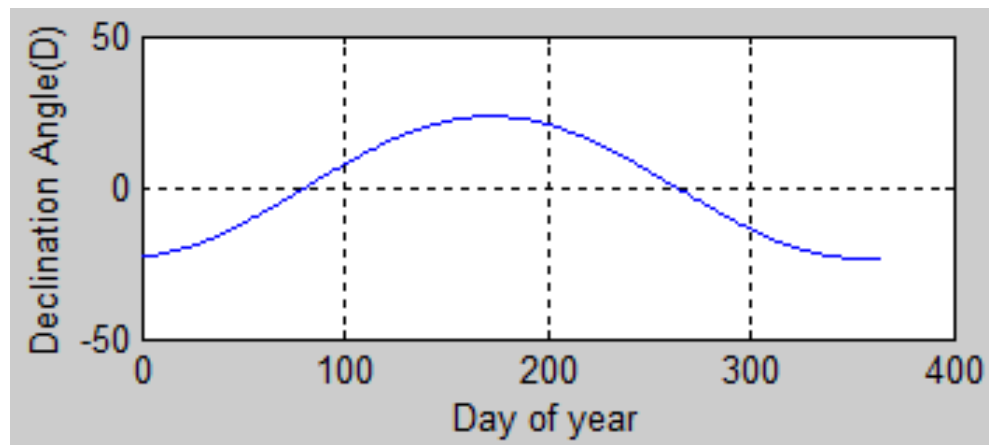


Figure (5.3) Relationship a Day of the Year and Declination Angle

Then the program calculates the values of angle of altitude (a) in each day of the year.

Then the implementation of the diagram shown in Figure (5-4) the relationship between the year days and altitude angle.

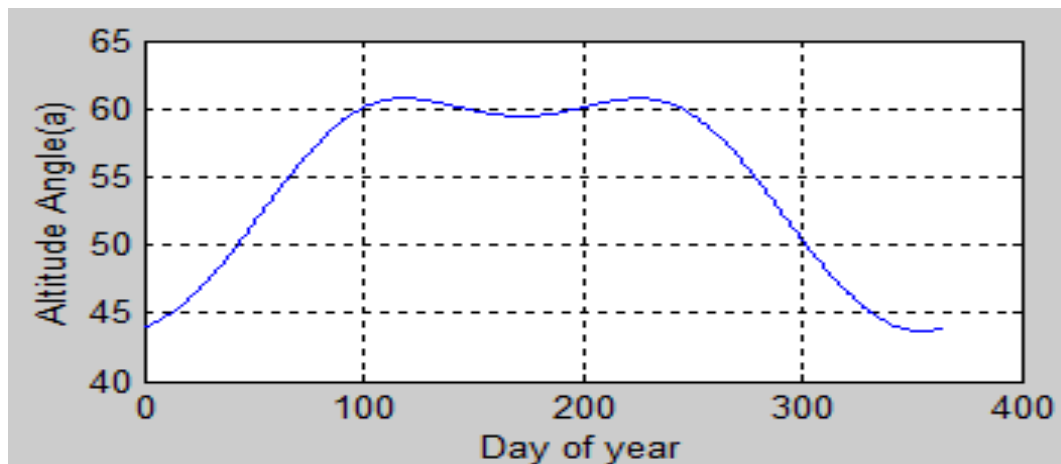


Figure (5.4) Relationship a Day of the Year and Altitude Angle

Then the program calculates the values of angle of Azimuth (a) in each day of the year.

Then the implementation of the diagram shown in Figure (5-5) the relationship between the year days and Azimuth angle.

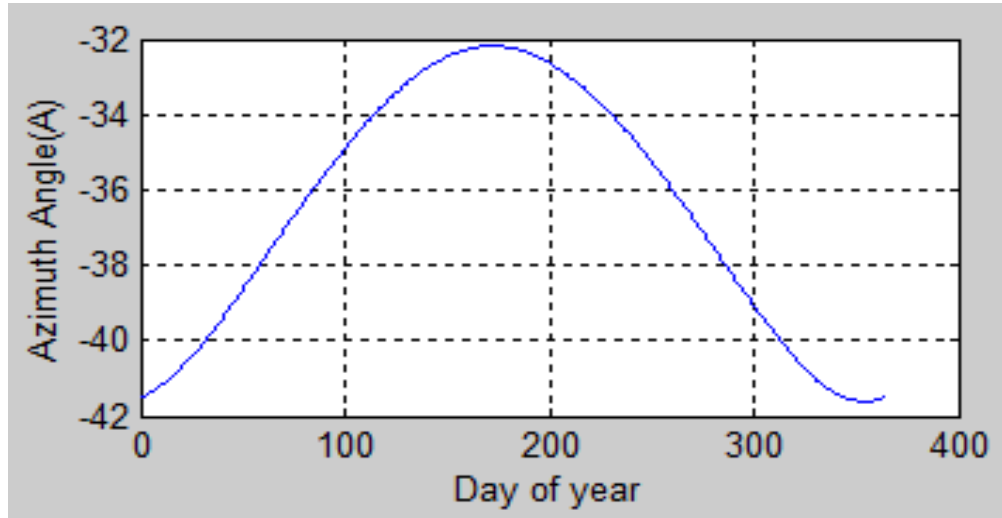


Figure (5.5) Relationship a Day of the Year and Azimuth Angle

Then the program calculates the values of angle of Incidence (I) in each day of the year.

Then the implementation of the diagram shown in Figure (5-6) the relationship between the year days and Incidence angle.

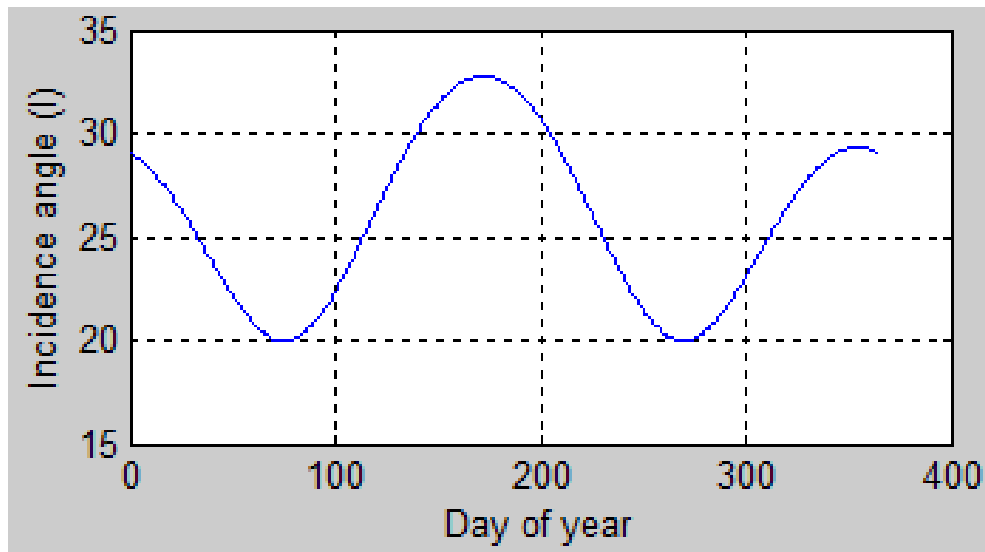


Figure (5.6) Relationship a Day of the Year and Incidence Angle

Then the program calculates solar radiation (I_{dn}), (I_{ds}), (I_t) and solar energy (E_t).

Then the implementation of the diagram is shown Figure (5-7) that the relationship between the year days and (I_{ds}) , (I_t) , (I_{dn}) , (E_t) is illustrated.

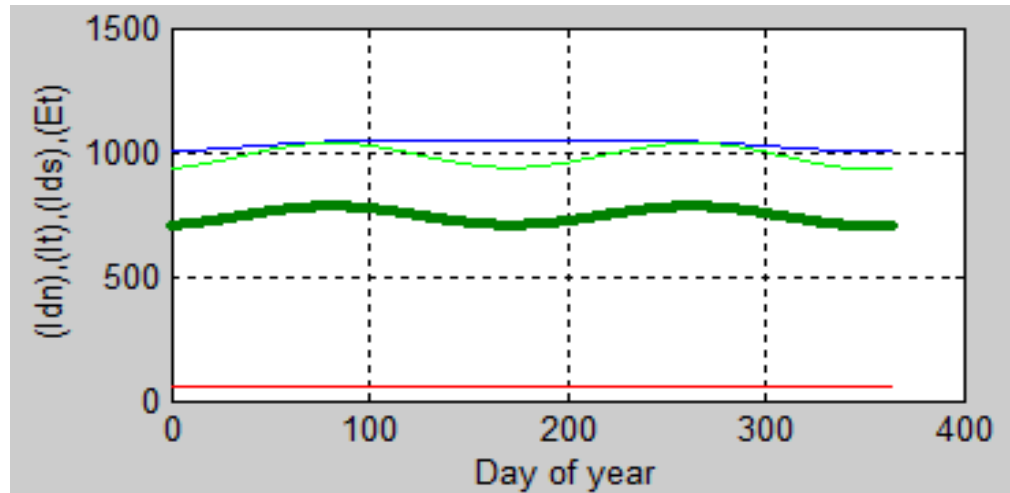


Figure (5.7) Relationship a Day of the Year and (I_{ds}) , (I_t) , (I_{dn}) , (E_t)

Then the program calculates of total solar energy required from the solar collectors (E_{in}) :

$$E_{in} = 1887 \text{ kW}$$

Then the program calculates of the dimensions of the solar collectors:

- (i) the dimensions of the dish solar collector:

$$\text{Diameter of the solar collector } (d) = 41.762 \text{ m}$$

$$\text{The output energy } (E_{out}) = 2830.4 \text{ KW}$$

$$\text{The efficiency of the solar collector } (eff) = 66.67\%$$

$$\text{The focus of the solar collector } (F_d) = 0.75 \text{ m}$$

- (ii) the dimensions of the parabolic solar collector :

$$\text{Diameter of the solar collector } (d_2) = 3 \text{ m}$$

$$\text{Length of the solar collector } (l_2) = 581.354 \text{ m}$$

$$\text{The output energy } (E_{out_2}) = 2830.4 \text{ KW}$$

$$\text{The efficiency of the solar collector } (eff) = 66.67\%$$

$$\text{The focus of the solar collector } (F_d) = 0.75 \text{ m}$$

CHAPTER SIX

CHAPTER SIX

6. CONCLUSIONS AND RECOMMENDATIONS

6-1 Conclusions:

- (i) The results of the program shown that comparing the dish collector with the parabolic collector that the dish is better in terms of size for the same efficiency and capacity.
- (ii) Matlab program has been used for the design and calculation of the efficiency and dimensions for both parabolic solar collector and dish solar collector.
- (iii) As a result of the program it has been found that the dimensions of 66.67% efficiency dish collector as diameter 41.762m and the dimensions of 66.67% efficiency parabolic collector as diameter 3m and length 581.354m

6-2 Recommendations:

- 1 / study the selection of hardware for the dish solar collector.
- 2 / design of a tracking system for the dish collector to improve the efficiency.
- 3 /design a cleaning system for the collector engaged with a tracking system for the collector.

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APPENDIX

APPENDIX A

LISTING PROGRAM

% Listing Matlab Program for Film Model

```
clear all;
clc
January =0;
February =31;
March =59;
April =90;
May = 120;
June =151;
July = 181;
August=212;
September =243;
October=273;
November=304;
December=334;
for y=[January February March April May June July August September October
November December]
if y==January
x1=1:31
n1=x1+January
Ae=1229.12;
Be=0.142;
C=0.058;
else if y==February
x2=1:28
n2=February+x2
Ae=1213.36;
Be=0.144;
C=0.060;
else if y==March
x3=1:31
```

```

n3=March+x3
Ae=1185;
Be=0.156;
C=0.071;
else if y==April
x4=1:30
n4=April+x4
Ae=1134.57;
Be=0.180;
C=0.097;
else if y==May
x5=1:31
n5=May+x5
Ae=1103.06;
Be=0.196;
C=0.121;
else if y==June
x6=1:30
n6=June+x6
Ae=1087.3;
Be=0.205;
C=0.134;
else if y==July
x7=1:31
n7=July+x7
Ae=1084.15;
Be=0.201;
C=0.136;
else if y==August
x8=1:31
n8=August+x8
Ae=1106.21;
Be=0.177;
C=0.122;

```

```

else if y==September
x9=1:30
n9=September+x9
Ae=1150.33;
Be=0.160;
C=0.092;
else if y==October
x10=1:31
n10=October+x10
Ae=1191.30;
Be=0.149;
C=0.073;
else if y==November
x11=1:30
n11=Nofember+x11
Ae=1219.67;
Be=0.149;
C=0.063;
else if y==December
x12=1:31
n12=Desember+x12
Ae=1232.27;
Be=0.142;
C=0.057;
end
end
end
end
end
end
end
end
end
end
end

```

```

end
end
end
subplot(3,3,1)
plot(x1,n1,'r',x2,n2,'g',x3,n3,'y',x4,n4,'m',x5,n5,'c',x6,n6,'b',x7,n7,'g-
',x8,n8,'k',x9,n9,x10,n10,'g*',x11,n11,'r.',x12,n12,'k:')
Xlabel('Day of month')
Ylabel('Day of year')
s=[n1 n2 n3 n4 n5 n6 n7 n8 n9 n10 n11 n12]
B=((s-1)*(360/365)*(pi/180))
E=229.2*(0.000075+0.001868*cos(B)-0.032077*sin(B)-0.014615*cos(2*B)-
0.04089*sin(2*B))
Subplot(3,3,2)
Plot(s,E)
Xlabel('day of year')
Ylabel('Equation of time')
grid
Stt=input('Stt=')
w=(Stt-12)*15
%Declination Angle(D)
D=23.45*sin((360/365)*(284+s)*(pi/180))
Subplot(3,3,3)
Plot(s,D)
xlabel('Day of year')
ylabel('Declination Angle(D)')
grid
%Latitude Angle(L)
L=input('L=')
%Altitude Angle(a)
a=(180/pi)*asin( sin((L*pi)/180).*sin((D.*pi)/180)+cos((L*pi)/180).*
cos((D.*pi)/180).*cos((w.*pi)/180))
subplot(3,3,4)
plot(s,a)
xlabel('Day of year')

```

```

ylabel('Altitude Angle(a)')
grid
%The hour angle at sunset or sunrise(ws)
ws= (180/pi)*acos(-tan((L*pi)/180).*tan((D.*pi)/180))
%solar Azimuth Angle(A)
A=(180/pi)*asin((cos((D.*pi)/180).*sin((w.*pi)/180))./(sin((a.*pi)/180)))
subplot(3,3,5)
plot(s,A)
xlabel('Day of year')
ylabel('Azimuth Angle(A)')
grid
%Slop Angle(B1)
B1=input('B1=')
%Incidence angle (I)
I=(180/pi)*acos(sin((D.*pi)/180).*sin((L*pi)/180).*cos((B1*pi)/180)-
sin((D.*pi)/180).*cos((L*pi)/180).*sin((B1*pi)/180).*cos((A.*pi)/180)+cos((L*pi)/1
80).*cos
((D.*pi)/180).*cos((w.*pi)/180).*cos((B1*pi)/180)+sin((L*pi)/180).*cos((D.*pi)/18
0).*cos((w.*pi)/180).*sin((B1*pi)/180).*cos((A.*pi)/180)+cos((D.*pi)/180).*sin((w.
*pi)/180).*sin((B1*pi)/180).*sin((A.*pi)/180))
Subplot(3,3,6)
Plot(s,I)
xlabel('Day of year')
ylabel('Incidence angle (I)')
grid
Idn=Ae*exp(-(Be./(sin((a.*pi)/180))))
F=((1+(cos((B1*pi)/180)))/2)
Ids=C*Idn*F
It=Idn.*(cos((I.*pi)/180))+Ids
Ee=input('Ee=')
Et=Ee*It
Subplot(3,3,7)
plot(s,Idn,s,It,'g',s,Ids,'r',s,Et,'.')
xlabel('Day of year')

```

```

ylabel('Idn),(It),(Ids),(Et)')
grid
%(ms) the amount of vapor
ms=input('ms=')
%(Cpw) heat quality water
Cpw=4.18;
%(T1) the temperature of water
T1=input('T1=')
%(T2) the temperature of piling water
T2=373;
%(Q1) the thermal energy needed to raise the temperature of water to temperature of
boiling
Q1=Cpw*ms*(T2-T1)
%(hfg) laten heat for at vapor when boiling point of the agenda of steam
hfg=2256.7;
%(Q2) the thermal energy to divert water to a steam
Q2=ms*hfg
%(hg)Enthalpy of the steam when the temperature of boiling water
hg=2675.8;
%(h) Enthalpy of the steam when the degree of roasting
h=input('superheat=')
%(Q3) the thermal energy for at vapor roasting
Q3=ms*(h-hg)
QTotal=Q1+Q2+Q3
%Q4 Loss energy
Q4=0.25*QTotal
%(Ein) Total energy required
Ein=QTotal+Q4
%dimensions of dish collector
f=((sum(Idn))/365)
d=sqrt((3/(pi*f))*Ein*1000)
Eout=0.5*(f/1000)*pi*d^2
eff=Ein./Eout
Fd=.75

```

```

ri=(1/(4*Fd))*(d/2)^2
%(Ad)area of dish collector
Ad = pi*(d/2)^2
%dimensions of parabolic collector
d2=input('d2=')
f=((sum(Idn))/365)
l2=((3/(pi*d2*f))*Ein*1000)
Eout2=0.5*(f/1000)*pi*d2*l2
eff2=Ein./Eout2
Fp2=.75
ri2=(1/(4*Fp2))*(d2/2) ^2
%(Ap)area of parabolic collector
Ap= d2*l2
end

```